MAY 1961

Journal

VOL. 53 · NO. 5

AMERICAN WATER WORKS ASSOCIATION

In this issue:

Front and center: Cobo Hall, Detroit, site of AWWA's 81st Annual Conference June 4–9

1961 AWWA CONFERENCE

Detroit, June 4-9

Journal

AMERICAN WATER WORKS ASSOCIATION

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May 1961

Vol. 53 No. 5

Contents

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Directory of Professional Services—pp. *68–74 P&R*

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AWWA ANNUAL CONFERENCE

Detroit, Mich. June 4–9, 1961

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Coming Meetings

AWWA SECTIONS

Spring 1961

Jun. 1–3—Canadian Section, at Prince Edward Hotel, Windsor, Ont. Secretary, A. E. Berry, 72 Grenville St., Toronto, Ont.

Jun. 20–22—Pennsylvania Section, at Galen Hall Hotel, Wernersville. Secretary, L. S. Morgan, County Health Dept., 50 N. Main St., Doylestown.

Jun. 27—New Jersey Section, at North Jersey Country Club, Wayne. Secretary, A. F. Pleibel, Dist. Sales Mgr., R. D. Wood Co., 683 Prospect St., Maplewood.

Fall 1961

Sep. 11–13—Kentucky-Tennessee Sec., Louisville, Ky.

Sep. 13–14—New York Sec., Saranac Lake.

Sep. 13–15—North Central Sec., Minneapolis, Minn.

Sep. 20–22—South Dakota Sec., Rapid City.

Sep. 25–26—Canadian Sec., Maritime Branch, Moncton, N.B.

Sep. 27–29—Wisconsin Sec., Milwaukee.

Sep. 28—Connecticut Sec.

Oct. 1–3—Missouri Sec., Springfield.

Oct. 2–4—Rocky Mountain Sec., Taos, N.M.

Oct. 4–6—Virginia Sec., Roanoke.

Oct. 5–6—Intermountain Sec., Twin Falls, Idaho.

Oct. 8–11—Alabama-Mississippi Sec., Biloxi, Miss.

Oct. 15–18—Southwest Sec., San Antonio, Tex.

Oct. 18–20—Iowa Sec., Cedar Rapids.

Oct. 25–27—California Sec., Sacramento.

Oct. 25–27—Ohio Sec., Toledo.

(*Continued on page 8*)

Coming Meetings

(Continued from page 6)

Oct. 25–28—New Jersey Sec., Atlantic City.

Oct. 29–Nov. 1—Florida Sec., Orlando.

Nov. 1–3—Chesapeake Sec., Baltimore, Md.

Nov. 13–15—North Carolina Sec., Asheville.

OTHER ORGANIZATIONS

May 15–16—Conference on "Water Pollution in the Great Lakes Area," sponsored by DePaul University, at the Pick-Congress Hotel, Chicago, Ill. Write: Lawrence Ragan, Public Relations Dept., DePaul Univ., 25 E. Jackson Blvd., Chicago 4.

May 23–Jun. 1—5th Congress, International Water Supply Assn., Congress Hall, West Berlin, Germany.

Jun. 6–8—National Congress on Environmental Health, School of Public Health, Univ. of Michigan, Ann Arbor, Mich.

Jun. 8–10—Manufacturing Chemists' Assn., White Sulphur Springs, W.Va.

Jun. 9–17—13th International Chemical Engineering Exposition and Congress, Frankfurt Am Main, Germany.

Jun. 18–23—AIEE, Ithaca, N.Y.

Jun. 26–Jul. 1—7th Congress, International Committee on Large Dams, Rome, Italy.

Jun. 25–30—ASTM Annual Meeting, Atlantic City, N.J.

Jul. 4–7—National Society of Professional Engineers, Olympic Hotel, Seattle, Wash.

SHORT COURSES

Jun. 6–8—5th Annual Appalachian Underground Corrosion Short Course, West Virginia University, Morgantown, W.Va. Write: John H. Alm, Rm. 605, 2 Gateway Center, Pittsburgh 22, Pa.

Jun. 19–21—Rudolfs Research Conference, Rutgers University, New Brunswick, N.J. Write: H. Heukelekian, Chairman, Dept. of Sanitation, Rutgers University, New Brunswick, N.J.

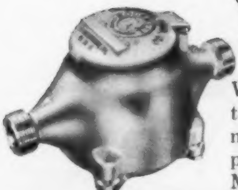
Jun. 19–30—Training Course on "Aquatic Biology for Engineers," Robert A. Taft Sanitary Engineering Center, Cincinnati, Ohio. Write: Chief, Training Program, 4676 Columbia Pkwy., Cincinnati 26, Ohio (or to USPHS regional office).

Jul. 10–Sep. 9—Training course on "Engineering Aspects of Radiological Health," R. A. Taft Sanitary Engineering Center, Cincinnati, Ohio. Write: Chief, Training Program, 4676 Columbia Pkwy., Cincinnati 26, Ohio (or to USPHS regional director).

Jul. 23–Aug. 4—10th Annual Utility Management Workshop, sponsored by Columbia Univ., at Arden House, Harriman, N.Y. Write: M. F. Garvey, 409 Engineering Bldg., Columbia Univ., New York 27, N.Y.

Jul. 24–28—Training course on "Recent Developments in Water Bacteriology," R. A. Taft Sanitary Engineering Center, Cincinnati, Ohio. Write: Chief, Training Program, 4676 Columbia Pkwy., Cincinnati 26, Ohio (or to USPHS regional director).

Joseph F. O'Grady



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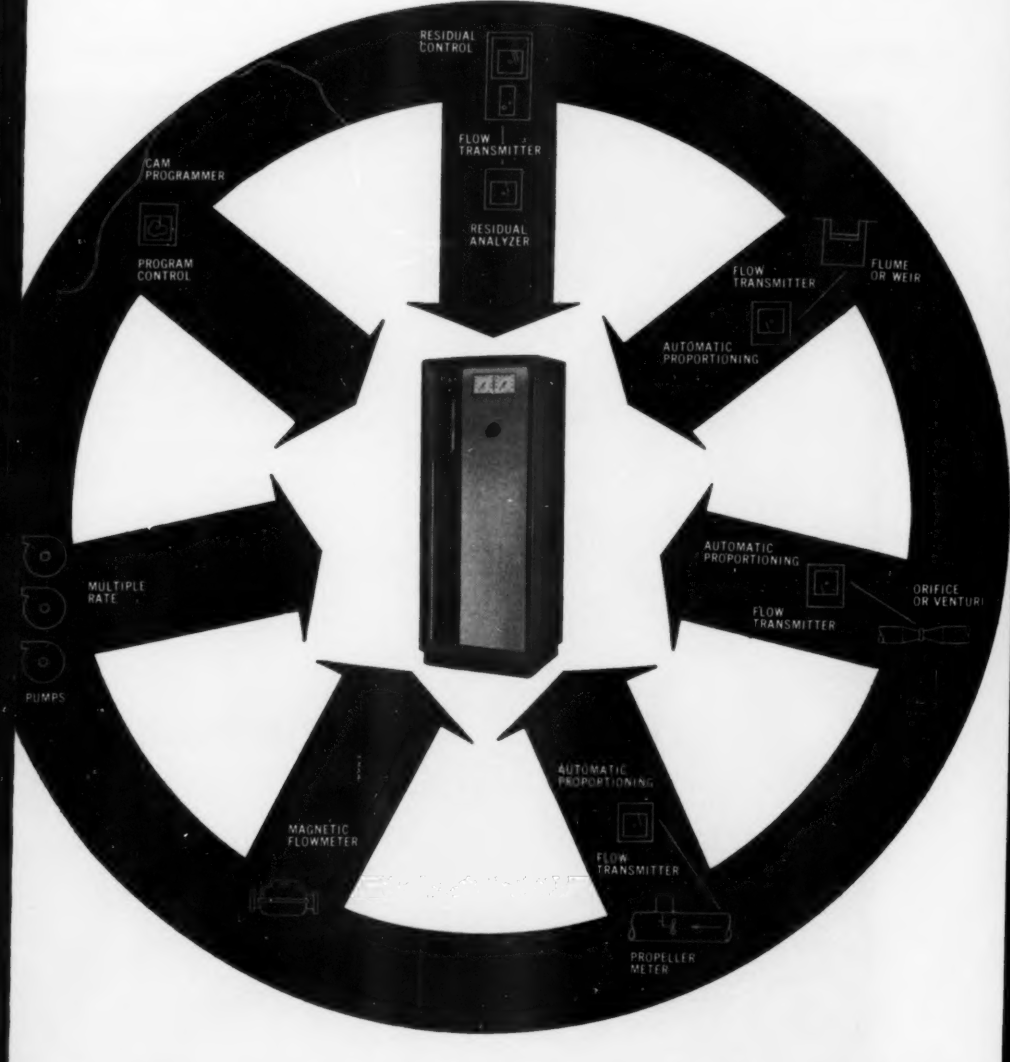

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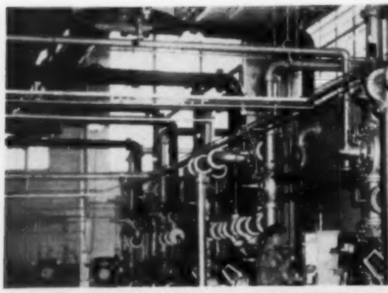

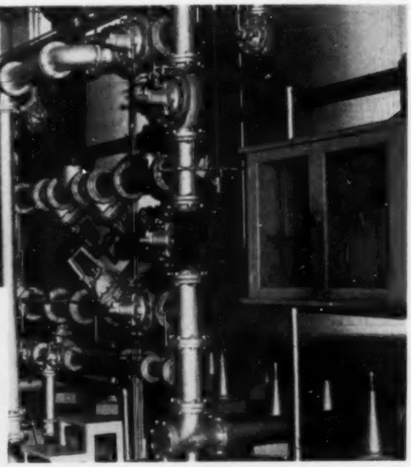

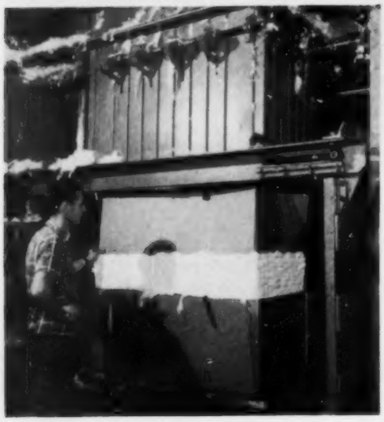

ABOVE: AMBERLITE® 200 is used in two softeners in this group. Here the durable polymeric structure of this resin successfully resists the action of "aggressive water" which shortens useful life of conventional ion exchange resins.

LEFT: Baling of rayon staple fiber at Lowland, Tenn., plant of American Enka Corporation.

Enka rayon plant solves "Aggressive Water" problem with AMBERLITE 200

At the Lowland, Tenn., plant of American Enka Corporation, water which has been chlorinated to breakpoint and softened is used for washing rayon staple fiber and yarn. Trace metallic catalysts present in the raw water combined with residual chlorine make the water passing through the softeners "aggressive" to conventional ion exchange resins.

When AMBERLITE 200 was installed in two of American Enka's ion exchange units, its revolutionary polymeric structure was the answer to "aggressive water". Wherever oxidation is a problem, AMBERLITE 200 gives longer resin life than conventional resins, and thus lowers operating cost.

Write for AMBERLITE 200 technical literature for more information on the performance of this resin. Also ask for a 16-page booklet illustrating the many different industrial uses of AMBERLITE ion exchange resins.

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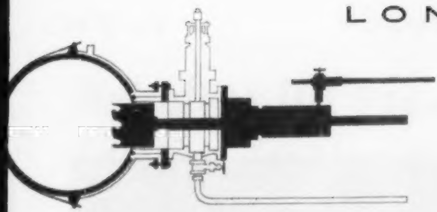
AMBERLITE 200



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Approved by the U. S. Public Health Service Technical Advisory Committee for use in treatment of public water supplies, Nalcolyte 110 speeds formation of tough, high-density floc as shown in the photos at right. In this case a single ppm of Nalcolyte 110 replaced 30 ppm of a conventional coagulant . . . *and produced a clearer water.*

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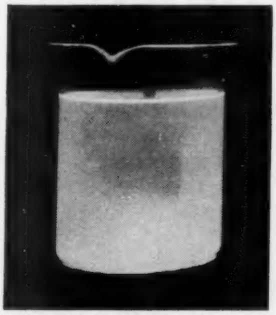
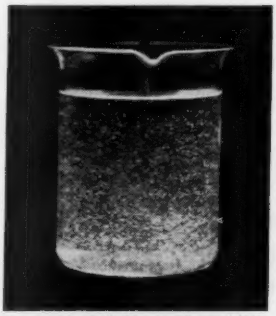
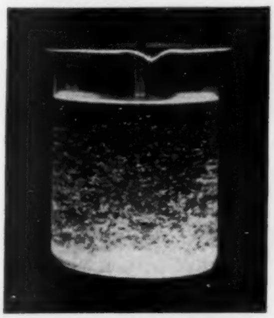


Untreated control sample of a turbid raw water.



Same water with 50 ppm alum added, photographed 7 seconds after ceasing agitation.



Same water with 20 ppm alum and 1 ppm Nalcolyte 110 added. Photo 7 seconds after stopping agitation shows rapid settling rate of larger, denser floc.

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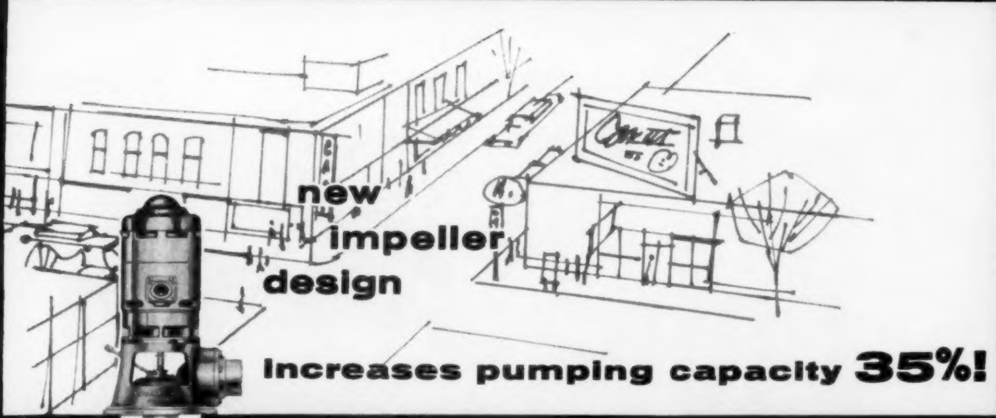

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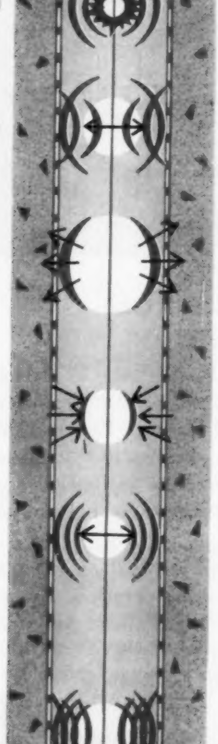

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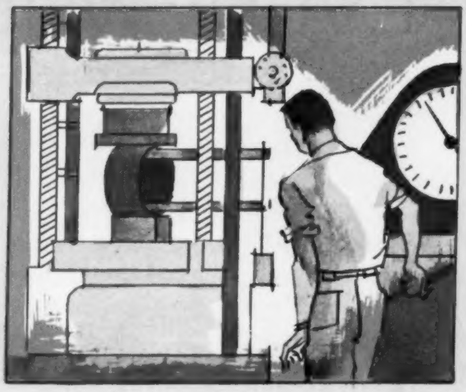

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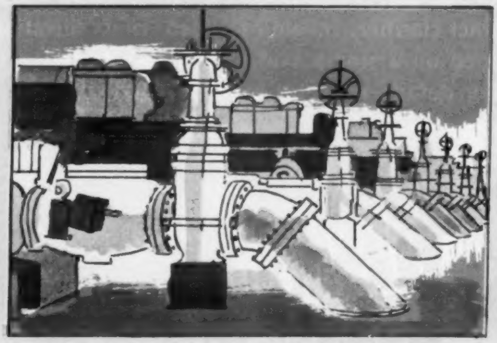

AMERICAN CAST IRON PIPE COMPANY
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Journal
AMERICAN WATER WORKS ASSOCIATION
VOL. 53 • MAY 1961 • NO. 5

Survey of AWWA Aims and Objectives

Committee Report

A report of the Ad Hoc Committee on Review of AWWA Aims and Objectives, submitted to the AWWA Board of Directors on Jan. 22, 1961, by Fred Eidsness, chairman. The Board then instructed the President to appoint a Steering Committee to develop a program based on the recommendations contained in the report. The Board also ordered that the report be published in the Journal prior to the 1961 Annual Conference, where the proposed program will be discussed.

THE aims and objectives survey was initiated by L. S. Finch in April 1959, during his term as President of AWWA. It was developed under the direction of a General Committee consisting of a chairman and two cochairmen, a consultant, and the chairmen of thirteen special-interest subcommittees. An Advisory Committee, consisting of those members who have provided continuing leadership in AWWA, was available for consultation by the General Committee. The specialized subcommittees were as follows:

1. Education
2. Engineering
3. Utility Finance and Accounting
4. Materials and Equipment
5. Operation and Management (Large Utilities)
6. Operation and Management (Small Utilities)
7. Public Health
8. Research
9. Section Secretaries
10. Service to Members
11. Water Quality and Treatment
12. Water Supply Industry Publications
13. Finances.

A progress report of this survey was presented at the 1960 Annual Conference in Bal Harbour and was subsequently published in *Willing Water* (September 1960). At the final Board of Directors meeting at Bal Harbour, the appointment of the Finances Subcommittee and a five-man Contact Committee of the Board was authorized. Only those facts will be repeated

which pertain specifically to this report and to the proposals which it contains.

The report should not be construed as a criticism of what has occurred in the past. The growth of this Association, both in numbers and stature, is a matter of record. Its present position as a scientific organization can be credited primarily to the staff, formerly headed by Harry E. Jordan, and to the long list of AWWA members who have given so freely and unselfishly of their time. But, in another sense, we cannot ignore the efforts of some 200 men who comprise this survey. They, too, have given of their time in order to advance further the aims and objectives which fulfill the primary purpose of any such organization—service to its members.

As one digests the reports of the first twelve subcommittees, there appear to be several ubiquitous subjects: advancement, education, engineering, programs and publications, and research.

In general, these subjects are under the jurisdiction of three standing committees—Standardization, Professional and Administrative Practice, and Technical Program. Although the chairmen and members of these committees have played the major part in the advancement of the Association to its present status, the results of its growth demand an increase in the number of such standing committees. The new standing committees could operate as separate entities in carrying out the recommendations of the several subcommittees applicable to their particular subjects, as well as having their chairmen serve ex officio as members of the Board of Directors.

We recognize from the opening paragraph of this report that the attainment of the goals of this survey requires a program, money, and time. We are indebted to the Membership Promotion Committee for its research into expanded membership classifications, which served as a guide for the Subcommittee on Finances. Ideally, no nonprofit-making organization can justify an increase in dues without knowing what added services will be forthcoming. But when Associate and Corporate Members were requested to consider payment of advance 1961 dues based on an increased schedule, what occurred? In large, these members replied affirmatively, not on the basis of a specific program, but with full faith in the destiny of this Association.

In the recommendations of this committee, we attempt to resolve in an orderly manner the requirements suggested by the subcommittees. We strongly feel that, with due diligence of all concerned, the expanded program can be defined and a dues structure can be initiated to support the program. This committee therefore recommends:

1. That, under the terms of Sec. 5 of Article 7 of the Bylaws, the Board appoint two new standing committees:

a. A Committee on Research, consisting of at least five members, and the chairmen of the Divisions, to be appointed by the incoming Board of Directors at each annual convention. The chairman of the committee shall be, ex officio, a member of the Board. [This committee has been formed.—*Editor*]

The Committee on Research shall develop a program of research, both basic and applied, in the broadest sense, make recommendations for the establishment of a permanent research foundation within the framework of the Association, and develop a program on this subject with the thought that at a later date a technical staff will be employed to implement the recommendations of the committee.

b. A Committee on Education, consisting of at least five members, to be appointed by the incoming Board of Directors at each annual convention. The chairman of the committee shall be, ex officio, a member of the Board. [This committee has been formed.—*Editor*]

The Committee on Education shall develop a program on education as applied to the water works field. It should review the recommendations of the subcommittees of this survey and develop a program on this subject with the thought that at a later date a technical staff will be employed to implement the recommendations of the committee.

2. That the Board refer the report of Subcommittee 4—Materials and Equipment to the Standardization Committee in order that noncontroversial recommendations falling under the jurisdiction of that committee be carried out immediately. On subjects which in the opinion of the Standardization Committee are controversial, that committee and the chairman of Subcommittee 4, with the assistance of the Executive Secretary, shall resolve any incompatibilities and jointly report their recommendations to the Board at its meeting in Detroit.

3. That the reports of the several subcommittees, with the exception of Subcommittees 4 and 13, be referred to the standing committees, the Divisions, and the Executive Secretary. After the recommendations of the subcommittees applicable to their particular jurisdictions have been studied, the standing committees, Divisions, and Secretary shall each report to the Board of Directors in Detroit. Such reports shall be forwarded to subcommittee chairmen at least three weeks prior to the meeting in Detroit, in order that the subcommittees may, if necessary, present a minority report to the Board.

4. That the Board adopt, in principle, Schedule 3 of the report of Subcommittee 13—Finances as recommended under Item 2 of that report. It is further recommended that the Board adopt, in principle, the recommendations of the Membership Promotion Committee to establish a membership classification for professionals and one for manufacturers' agents or suppliers.

5. That the Board, in principle, adopt the thesis that a share of the funds collected under a new dues schedule be allocated to the Sections, recognizing that the ultimate success of an expanded Association program requires accelerated interest, activity, and coordination of efforts at the local level.

6. That the Board adopt Recommendation 3 of Subcommittee 13 relating to a management consultant. The President, with the approval of the Board, shall appoint a committee whose responsibility will be to:

a. Determine the scope of the activities of the proposed management consultant.

b. Interview management consultants and, with Board approval, effect employment.

c. Advise with such consultant before and during the survey.

d. Upon receipt of the report of the consultant, present final recommendations to the Board covering future Association activities.

7. That this report and the appendix containing the several subcommittee reports be published in full in the JOURNAL of this Association.

In closing, we must acknowledge the efforts of the thirteen subcommittees and the cooperation of the Association staff.

Committee on Review of AWWA Aims and Objectives

F. A. Eidsness, *Chairman*
C. G. R. Armstrong & C. P. Harnish, *Cochairmen*
L. S. Finch, *Consultant*

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W. A. Hardenbergh, *Cochm.*
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H. P. Kramer
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R. E. Stiemke
W. H. Walkinshaw

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APPENDIX

Following are the reports submitted to the General Committee by the various subcommittees

1. Education

Water works short courses are of primary concern in any educational program of AWWA. Water works short courses are now usually given in most areas by local groups including AWWA, state departments of health, and engineering colleges. There is general agreement that these courses are successful and should be continued. They should be conducted at the local level so as to be available to the greatest numbers of personnel. However, the fact that they are "good" appears to be about all that is common to the various courses.

There is wide variation in the educational level of subjects covered, the number of people attending, the educational background of those attending, the objectives of the courses, the methods of teaching, and the number of courses offered. It is even questioned whether some of the courses at the local level are serving the purpose for which they are intended. If the courses are to continue to serve their purpose, they must provide operators with a better understanding of their operation problems, and this must be done for the technically educated man in the large water works, as well as for the operator of the smallest village department. Obviously this cannot be done in a single short course.

For successful courses, a large amount of written material is needed for the students, and visual aids can often be used to develop some of the basic concepts in the classroom. If the student is to receive maximum benefit, the written material should be in book form, with full descriptions and illustrations. Books are kept and referred to, while lecture notes and mimeographed material are seldom referred to after their initial use.

It is apparent that there has been much duplication of effort in preparing even the courses now given in the different states. If the course standards are to be raised, preparation at the local level becomes impractical.

AWWA would be providing a real service to its members and the water works industry if it sponsored or cooperated in sponsoring a series of operation manuals or texts and visual-aid material for short-course use. There is at the present time no satisfactory general text, and it seems unlikely that one will become available unless sponsored by some group such as AWWA. For example, the Engineering Extension Service of Texas A&M has prepared an excellent set of operations manuals for Texas operators. Booklets such as these, but revised to apply to the nation as a whole, would make an excellent start. Since the state sanitary engineers have the primary responsibility for the maintenance of water works operation standards, such a project should not be carried on without their cooperation. It is suggested that AWWA consider cooperating with the state sanitary engineers in the sponsorship of such a series of course manuals and visual aids.

A strong educational program for operating personnel cannot be considered without at the same time establishing standards for the operating person-

nel to meet. Such standards are most easily promulgated through operator certification programs, either compulsory or voluntary. It is obvious that compulsory certification must be handled at the same level by the proper legal authority, and voluntary programs should probably also be administered at the state level. Operator certification is one of the most effective means for raising the standards of operation, and AWWA could assist the program by supporting the development of standard classifications for operator certification and standard examinations which could be used by the state agency administering the program. Although the state agency would not be obligated to follow AWWA recommendations, the existence of a standard would surely raise the level of most programs—certainly of the voluntary programs.

Another matter that should be of concern to AWWA is the inability of the water works profession to attract college-educated technical personnel. The operation of a city water utility involves many problems of engineering. Many of the older superintendents are graduate engineers, but there are relatively few young engineers entering this branch of the profession, far fewer than the number required for replacement. Much could be done at the local level to attract graduate engineers—for example, by offering summer employment to engineering students and providing them with challenging work early in their careers. AWWA could encourage this type of program by giving publicity to companies or departments that undertake such programs and by showing how the young engineer can be effectively utilized in water utility organization.

It is not difficult to suggest many programs for AWWA, but it is exceedingly difficult to envision how these programs are to be carried to a successful completion. In the above paragraphs it has been proposed: (1) that AWWA support the preparation of short-course text and visual-aid material; (2) that it establish standards for operator certification and prepare certification examinations; and (3) that it attempt to aid in a program to attract young technical graduates to the profession. Much could be accomplished toward carrying out these objectives through the voluntary effort of the membership by committee action. However, it is doubtful if committee action would be enough, particularly for Items 1 and 2. In order to be assured that this program will be carried to a successful conclusion, it is suggested that a man be employed for the purpose. This is not a job for a beginner. Possibly a teacher with experience in writing short-course material could be induced to take a leave of absence and devote a year to the preparation of text material to start the program. Thereafter it could be continued by summer employment of the same person or someone similarly well qualified. Because the program outlined is so directly concerned with the responsibilities of the individual state sanitary engineers, it is recommended that AWWA work with the Conference of State Sanitary Engineers and, if necessary, finance the program to get it started.

As an alternative proposal for carrying out this program, particularly Items 1 and 2, it is recommended that an attempt be made to obtain the support of the USPHS. Certainly this agency of the government is primarily

concerned with water quality, and the use of federal funds would appear to be well justified for such an educational program.

If AWWA will spearhead the above program, it will be providing a maximum service to the entire membership and to the profession. If it is undertaken, it is important that it be done well to be of maximum use to the profession. For this reason it is recommended that the responsibility be placed with someone who can devote his time exclusively to this project for at least a year to get it started. It makes little difference whether his immediate support comes from AWWA, the Conference of State Sanitary Engineers, or some other agency such as USPHS. It is important that the job be undertaken.

2. Engineering

This subcommittee was asked to:

1. Appraise current AWWA activities as they relate to engineering.
2. Consider and evaluate new areas of activity.
3. Recommend and list in order of priority means and methods of improving the current AWWA program to make it of greatest practical value to the water supply industry, to the public, and to AWWA members.
4. Consider and recommend means of promoting AWWA membership among engineers.

AWWA Publications

The Journal. An analysis of the subject matter of the articles published in the JOURNAL showed that the great majority cover phases of engineering in the branches which relate directly to or are closely allied with water works and hydraulics. The contents include not only highly technical and theoretical articles but also some that are well prepared in simple language easily understood by the laymen. This is as it should be since the membership is made up of engineers, technicians, operators of all grades, laymen, and public officials.

One of the valuable items in the JOURNAL is the annual subject index, which is well composed in a readily usable form. There was some criticism that the *Cumulative Index* [published in book form and covering the period 1940–1955] does not provide a similar detailed breakdown by subject in alphabetical order but instead lists the titles of articles topically, using relatively broad categories.

Generally, the technical articles of the JOURNAL are prepared by engineers and are therefore written in engineering terminology; they contain appropriate charts, tables, and graphs to illustrate the text, but are sometimes deficient in photographs or detail drawings. Because the JOURNAL is accepted by the public as authoritative, the articles published should be carefully screened for accuracy. The JOURNAL as it is now published appears to be satisfactory from an engineering aspect.

For convenience in filing and use, it is urgently recommended that the size, physical makeup, and format of the JOURNAL not be changed.

Willing Water should not include material of an engineering nature but should be kept completely nontechnical, covering the fields of public relations, membership, and other items of general public interest. It is now published in a form and size convenient for filing and binding, and should remain in this form. Care should be taken that it does not grow in volume.

Manuals, Reports and Pamphlets. A review of AWWA manuals, reports, and pamphlets indicates that

most engineering aspects of the water works industry are quite well covered. The present system of AWWA standards is achieving good results and will continue to do so.

The Association *through its publications* can render the greatest service to the membership and the public its members serve by confining its activities to advancement in the technical and practical fields of planning, financing, maintaining and operating public and private water supply facilities, and the cultural advancement of the membership, leaving to others welfare and social affairs.

Research Activities

Considerable work has been and is continuing to be done on various research projects under the direction of the different Divisions of AWWA, and much benefit has been derived from this research. The water works profession, however, is far behind other large industries in the proportionate amount of research that is being undertaken. A myriad of old and new technical and engineering problems attend the present-day demand for better and greater water supply service.

The call for research as expressed and discussed by Faber, Jordan, and Larson in the November 1959 issue of *Willing Water* is commended.

It is recommended that a working technical research committee be organized within the framework of AWWA, with across-the-board representation from all four Divisions, and that action be inaugurated, along the lines and in the order listed below, toward the possible formation of an "AWWA Research and Development Foundation."

1. Organize an interim general committee on research and development to study and investigate the desirability and ways and means for establishing an "AWWA Research and Development Foundation" within the framework of the Association.

2. Organize cooperating research task groups within appropriate technical committees of the four Divisions of AWWA as liaison advisory contacts for the above general study committee, to identify and appraise the various problems from the different areas of the water works industry from the standpoint of needed research on a local, regional, national, and, perhaps, international basis.

3. Have the research study committee review the above findings and list and determine the order of priority of selected projects in terms of breadth of interest and potential for greatest return and benefit; then publicize them for membership consideration and comment as a guide to assist in the preparation of an acceptable and equitable program of possible research projects.

4. Develop a working program of research projects in order of their established priority, including a suggested tentative preliminary plan of procedure for exploration.

5. Concurrently review the organizational setup and mechanics of typical research programs of other association-type organizations and utility groups (such as the American Gas Association and the Edison Electrical Institute).

6. Establish liaison with similar committees in allied fields and with technical societies interested in water works research problems.

7. Arrange for submitting periodic summary reports of progress to the AWWA membership.

8. Present a final decision and recommendations on AWWA research and development activity for the future.

Distribution Division Activities

The members of the Water Distribution Division have been very active in program planning and committee and task group participation, much of which has been closely related to engineering. This work will continue.

Suggested new areas of activity include: (1) to make, and publicize the results of, product evaluation, particularly new products and equipment; (2) to solicit and publish papers and reports of interest to the Division on engineering and research by nonmembers associated with research organizations and universities; and (3) to establish engineering short courses of 1–2 days' duration in cooperation with university engineering schools on subjects such as automation, hydraulics, metering, hydraulic sensing devices, equipment review, and maintenance practices.

Methods of improvement of the engineering aspects of the activities of the Division include:

1. To review programs presented at the annual conference and establish a subcommittee under the general program committee to solicit and screen topics for future presentation.

2. To review the status of all divisional committees and determine those that should be inactivated and those that should continue.

3. To review all adopted standards in the distribution field and determine which, if any, are in need of revision.

4. As manpower becomes available, to appoint new task groups to consider the need for writing standards for equipment items such as rotating, cylindrical, or ball valves, venturi meters, ductile-iron pipe, corporation stop valves, and other items associated with service lines.

5. To appoint a committee or task group to study the desirability of AWWA's sponsoring research in the following fields:

a. Loss-of-head data for system components, such as check valves and reducing elbows.

b. Current density required to protect ferrous materials in waters of different chemical characteristics.

c. Water hammer within the distribution system.

d. Protective coatings, particularly exterior paints and epoxies.

e. Factors affecting water main breaks.

Resources Division Activities

A critical inspection of the Water Resources Division indicates that it is providing the engineer information about the potential and developed sources of public water supply and about experience with such developments that is unique among engineering associations and professionally valuable.

Suggestions that could improve the value of the work of this Division to engineers include:

1. To maintain in the future the broad base of interest for which the Division was originally created and which it has been pursuing. The Division must remain with a broad interest, as the public water supply industry is competing increasingly with other water users.

2. To review the status of all committees and task groups in AWWA within the field of interest of water resources and activate or terminate those which are dormant without good reason.

3. To make charters of future committees and task groups sufficiently

specific and specialized as to provide a good base for a report and normally plan on termination following that report.

4. To establish a specific working relationship between the Division and the Committee on Standardization to achieve coordination between committee and work group assignments.

5. To make an analysis of the articles published in the JOURNAL during the past few years and determine if the coverage of the engineering phase of the Division's field of interest is properly balanced.

Committee Activities

The Standardization Committee and the Committee on Professional and Administrative Practice devote a large portion of their time and effort to problems of an engineering nature. Both committees deserve the highest praise for the work they have done and are doing. They both have the constitutional framework and well thought out organization system to allow for continued and expanded subcommittee work on any subject deserving attention.

It is suggested that major committee chairmanships should not be perpetuated. Competent dedicated persons should remain active on the committees, but fresh viewpoints should be introduced periodically at the top. If a time limit on the service of a chairman were recognized, there would need to be no embarrassment when changes seem desirable.

Convention Programs and Exhibits

The quality of both section meeting programs and exhibits from an engineering standpoint largely varies with the ability of the local chairmen and the facilities available. At the annual AWWA conference, the general program chairmen are usually very capable. However, the programs developed within the different Divisions at the annual conventions often show the lack of experience of the persons arranging for the papers.

Membership Promotion

The pertinent point is not the promotion of AWWA membership among engineers, but instead the direction of engineers to the water utility field. From this would automatically follow membership in AWWA.

One facet in attracting engineers to the industry is providing adequate remuneration. The Association could take a more active interest in promoting and seeing to it that water utility engineers receive compensation equal to that of engineers in other fields.

The establishment of additional suitable scholarships by AWWA is suggested as a means of bringing to the attention of boys in high school and college the opportunities in the water utility field. These scholarships could be solicited from anyone or any group connected with the water industry.

A survey of the members of AWWA to obtain data on age groups, educational rating, job classification, salaries, and other factors of interest is suggested as a possible means of analyzing our strength or weakness, so as to determine in what direction our efforts should be steered to help remedy our defects.

The engineering phase of the water industry should receive greater publicity.

Conclusion

In general, the engineering phase of the water utility profession is quite well

covered. Some of the specific recommendations made would probably improve the quality of the services rendered to the engineers in certain fields. These recommendations should be explored further by the specific group concerned.

The quality of service being rendered by AWWA should be reviewed and evaluated at intervals, say every 5–10 years, to insure the continuing satisfaction of the members and a continuing healthy growth.

It is recommended that a working technical committee be organized within the framework of AWWA with across-the-board representation from all four Divisions, to be known as the "AWWA Research and Development Foundation," to direct and coordinate the research activities of the Association.

An increase in membership will come with the recognition that AWWA is rendering a high-caliber service to every person connected with any phase of the water industry. From an engineering standpoint, the subject matter and method of presentation of technical papers at the conventions and in the JOURNAL is most vital. Interest in the water utility field as an engineering career could be furthered by having members address groups of high school and college students, particularly student chapters of AIChE and ASCE. Every member should have AWWA literature displayed for visitors to see and use, and should have an application readily available for anyone expressing an interest in the Association.

Every member should make himself a committee of one to sell other members of his organization on the value of AWWA membership, particularly the assistant and subprofessional groups.

The Association is presently providing a valuable service to engineers in the water utility field, and by constant guidance from engineers active in the profession it will continue to do so.

3. Utility Finance and Accounting

This subcommittee reports as follows:

Publications

The Journal, for the years 1958 and 1959, is to be commended for the well chosen series of articles relating to the subjects of finance and accounting. Previous years do not show a similar coverage. It is recommended that each issue of the JOURNAL include items of interest on these subjects.

Willing Water should incorporate items of interest on subjects relating to finance and accounting, although its format is not as adaptable to dissemination of this type of information as is the JOURNAL. Perhaps the inclusion of items on a three to four times per year schedule can be arranged.

Manual of Water Works Accounting. This is an excellent contribution to water works operation literature. Its date of publication suggests that it should be reviewed for the incorporation of developments in water works operation and accounting. [A joint committee of AWWA and the Municipal Finance Officers Association, which cosponsored the current edition, has been formed to prepare a revision.—*Editor*]

The possibility of adding a section, or perhaps a supplemental volume, dealing with simplified accounting methods for small water utilities, de-

fined as those with less than 5,000 customers, should be investigated. [This matter has also been assigned to the above committee.—*Editor*]

Survival and Retirement Experience With Water Works Facilities. This book was published in 1947 and includes data from early years up through the early 1940's. The book should be brought up to date by adding the experience of the past 15–20 years, and a program instituted whereby future revisions may be made at, possibly, 5-year intervals. It may also be desirable to expand the number of systems contained in the study, or to refine the study to differentiate, for example, the various types of main joints that have been developed since World War II.

Rates Manual. This manual was published in 1954 and, like the other publications mentioned, should be reviewed to include new cost data and developments in water rate analysis and experience. An annual supplement might contain actual rate schedules in effect for water utilities. [This manual was reviewed by the committee chairman in 1957 and minor changes were made.—*Editor*]

Management Manual. This manual was published in 1959 and is therefore current. No revision is recommended.

New publications. It is recommended that a water utility financing manual be prepared, perhaps in conjunction with the National Municipal League or some other interested group. The manual would present the various methods of financing, with attention given, for example, to general-obligation bonds, revenue bonds, combination bonds, short-term financing, cash financing, and policies regarding extension financing by contribution and advances, revenue contracts, and other features. Such a manual would include a model revenue bond resolution, and would point out from the standpoint of the water utility various necessary and beneficial provisions, as well as the overrestrictive and unnecessary features sometimes urged by bond buyers. The manual could also discuss the limitations of revenue bond financing. A discussion could be included regarding enabling legislation for utilities in localities where needed.

Research Activities

It is recommended that a survey be made of the current practice in the following fields, and that the results of these surveys be published: (1) the insurance requirements of a water utility, (2) policies of main extension and replacement, and (3) meter ownership and replacement.

Committee Activities

A review of committee titles relating to finance and accounting indicates that a number of committees operating in this field may have overlapping functions.

A review of these committees' functions may be in order, and, if found warranted, consolidation in some instances may be effected.

4. Materials and Equipment

This report is divided into three principal sections: (1) changes or revisions of present standards; (2) items for which standards should be established; and (3) mechanics of handling new standards and disseminating information to AWWA members.

Existing Standards

The following are suggested changes in standards which the majority of the committee feels should be made:

B400 (*ammonium sulfate*). This standard should be moved from the B400 coagulation series and placed in a new category, such as B800, to be called "ammoniation."

B601 (*sodium pyrosulfite*). The name should be changed to "sodium metabisulfite." Although technically correct, the name used in the standard is almost unknown, and water systems purchase the chemical under the name of "metabisulfite."

C300 (*concrete pipe*) is being reviewed by Committee 8320 D, which will have some changes to suggest. It is recommended that a suitable committee on valves give consideration to standard facing and drilling on tapping valves. This committee should also give consideration to standardizing the spigot end of reinforced concrete pipe and providing for design of the bell end of the pipe so that the spigot from one manufacturer will fit into the bell of another manufacturer. Variations in design should be confined to the bell end in such a way that pipe from one manufacturer can be used with that from another manufacturer. Standards of this type have already been achieved in the eastern part of the United States and should be made uniform for the entire industry. There should also be standards for 300-psi ring flanges. Comments made above also apply to standards C301 and C302.

C400 (*asbestos-cement pipe*). Section 5 should provide modification of permissible diameter reductions and should also provide for 10-ft lengths of pipe when desired by the purchaser. Section 6 should call for the establishment of adequate design criteria or, in lieu thereof, the establishment of minimum wall thickness. In Sec. 8, all tests, including crushing tests, should be made mandatory. In Sec. 9, the alkalinity test should be replaced by a test for uncombined calcium hydroxide.

C500 (*gate valves*). Section 2 defines the limits to which this standard applies in various pressures and sizes. It is recommended that the committee on valves give thorough study to the possibility of enlarging the scope of the standard to cover sizes up to and including 72 in.

Section 16.4 specifies that the diameter of stems at the base of the thread shall be not less than those shown in Table 2. This wording should be clarified to make certain that the stem diameter shall be not less than that specified in Table 2 at any point on the stem, including the base of the thread.

Section 19 should be modified to require that an adequate design shall be determined to allow for the maximum stress anticipated without exceeding the yield point of the metal, either in the bolts or in the follower gland.

Section 27 calls for a coating which is unsatisfactory. It is recommended that the committee determine what protective coatings are satisfactory for valves and then specify them with precision as to thickness and durability. Adequate coatings should be provided for both internal and external uses. The section dealing with pressure ratings and test pressures should be reviewed for adequacy, clarity, and consistency. The section on performance testing should be reviewed for clarity.

C700 (*displacement meters*). Section 3.3.2.2 refers to an ASA standard, B16.1, which is being revised and is unobtainable. A reference standard should be one that can be readily obtained. The diameter of the bolt holes in the oval flanges should be specified.

Section 3.4.1 should be referred to the meter committee with a request

that consideration be given to standardizing round-reading registers with respect to direction of rotation and sequence of dials. This is standard in all meters used by utilities, except water. It is also recommended that the meter committee give consideration to reducing the permissible head loss in meters. The manufacturer's serial number should be a combination of letters and numbers, not exceeding a total of six digits.

C702 (compound meters) should incorporate the changes listed above for C700. It is recommended that the meter committee give serious consideration to standardizing the dimensions for compound meters with reference to overall length of the meter and the distance from the center of the bolt circle to the base. The accuracy test for compound meters should have a specified ratio of accuracy, with both increasing and decreasing flows. It has been found that in some instances the compounding valve will not close at the proper time on decreasing flows, which results in gross inaccuracies.

C800 (service line fitting threads). Figure 1 should include plain tapered extensions at the outlet. The wording in Table 1 now reading "taper per foot" should be changed to read "taper per foot across diameter." Figure 2 and the last column of Table 2 specify minimum lengths which exceed those actually being made. Such length is unnecessary. The last column in Table 3 should include a maximum length as well as a minimum, to avoid conflicts when tube and nut are not machined together.

New Standards

The committee recommends that suitable committees be appointed to prepare standards for the following items not now covered by AWWA standards:

Centrifugal pumps. The only present standard for pumps is for the deep well type.

Treatment plant equipment. Suitable standards should be prepared for such components as rate-of-flow controls, head loss and sand expansion gages, and similar equipment used in filter plants. There are also no standards for any type of chemical feed machines. At least basic standards of accuracy and feed limit rates should be established for all types of chemical feeders for liquid, gaseous, and solid chemicals. It is recommended that suitable committees be appointed to prepare standards in these areas and that such committees define terms and basic standards to be used.

Treatment chemicals. It is felt that suitable standards should be prepared for the following chemicals which are not presently covered by a standard: anhydrous ammonia, ammonium hydroxide, sulfur dioxide, sodium hexametaphosphate, sodium tripolyphosphate, tetrasodium pyrophosphate, disodium phosphate, sodium sulfite, sulfuric acid, sodium chlorite, potassium permanganate, sodium bichromate.

Spigot ends. The committee for cast-iron pipe and fittings should determine a definite standard for the spigot end of all cast-iron pipe. Suitable allowance should be made in the design of the bell and gasket to permit variations between manufacturers, but the spigot end from one manufacturer should fit the bell from another manufacturer where the rubber ring cast-iron pipe joint is used. The committee may desire to consider the possibility of standardizing dimensions for the rubber ring joint so that both spigots

and rubber rings will be interchangeable. This is not made as a firm recommendation, however.

Laying pipe. Standards similar to the one for laying cast-iron mains should be prepared for all other types of pipe material, especially steel, reinforced concrete, and asbestos-cement.

Valves. Standards similar to those for gate and butterfly valves should be considered for other types of valves used in the water industry, such as cone, plug, ball, pressure-regulating, and air-relief and vacuum valves.

Meters. Basic standards should be considered for venturi meters, large-line impeller meters, and gentile tubes.

Service line materials. Corporation and curb stops are presently being used which do not meet the criteria for good products. The waterway in curb stops is frequently quite small, and the machine work is not accurately done. A full set of standards specifying general design, metal content, and machine finishing should be prepared for all service line materials and fittings.

Couplings. Consideration should be given to the preparation of standards for couplings of all types, including rubber and metallic couplings, and for expansion couplings. There are presently no standards in this area.

Electrical equipment. Investigation should be made of the existing standards of the Instrument Society of America for instruments and equipment used in the electrical field. Some inferior material is now being used because the basic standards do not require proper insulation, drainage, and protection against moisture.

Grounding. Consideration should be given to the preparation of basic standards governing the grounding of electrical equipment to water pipe. It is recognized that AWWA has objected to grounding electrical equipment to water pipe, but this is general practice. If the water industry has to live with this situation, there should be some basic standards governing the practice.

Testing. Consideration should be given to the requirement of testing all water works products in the United States. Factory inspection of foreign-made goods is difficult and costly, and damage from shipment should be determined before the product is installed.

Standardization Procedures

Present methods of developing new AWWA standards are cumbersome and time consuming. There should be a more expeditious manner for the preparation and adoption of new standards and for the revision of existing standards. [A proposed standardization procedure, prepared prior to the submission of this report, is now under study by the Executive Committee.—*Editor*]

The subcommittee recommends that a standards committee be appointed in each area of water works products once each year, with members subject to reappointment if recommended by the chairman of the committee. The chairman would designate one or more qualified members of his committee to draft the basic standard. This standard would then be referred to all members of the committee for review and comment. After the standard has been redrafted in accordance with committee comments, it would again be circulated to members of the committee for final approval. The approved standard would then be sent to the Standardization Committee.

It is recommended that a period not exceeding 4 months be allotted for the preparation of the basic standard and that the approved standard be submitted to the Standardization Committee not later than a year after appointment of the committee.

It is recommended that each standards committee report to the Standardization Committee at least once a year, whether there has been any committee action during the year or not. At least once every 3 years the standards committee should review the standards under its jurisdiction and consider revisions and modernization, or elimination of a standard if it is not being used.

The chairman of each committee should recommend the reappointment of those members who have taken an active part in the committee work, and recommend the dropping of those who have not done their share of the work. This will aid in eliminating much of the deadwood present on some of the committees.

Manufacturers' committees similar to the Steel Water Pipe Manufacturers Technical Advisory Committee, which was organized a number of years ago and has the official recognition of the AWWA Board of Directors, should be appointed in many other areas and recognized by AWWA to give them some official status. The rules and regulations of the steel pipe committee would be a good model to follow.

It is strongly recommended that a full-time qualified engineer be employed to review existing standards, to coordinate the preparation of new standards, working with each of the committees, and to coordinate research and development work on new materials and equipment. This person could also act as a clearinghouse for information relative to materials and equipment. [A standards engineer has already been added to the AWWA staff.—*Editor*]

It is recommended that water works operators be asked to notify AWWA when they encounter any difficulty with a product furnished under an AWWA standard. In this way, a fund of information would be accumulated which would be of value in enforcing or revising the standards.

The development and production of new types of materials and equipment should be given better publicity and more recognition by the Association; a series of articles should be prepared for *Willing Water* on new methods and new equipment. It is recommended that, at all Section meetings, program time be allotted for description of new equipment and discussion regarding its use.

A review of new materials and new techniques in the water utility field should be made, with special attention to such products as plastics for water mains and service pipe, and the use of electronics in water system control. It may be advisable to establish new committees to review these fields and prepare basic material for the use of the industry.

It is recommended that a procedure be established for applied research in the field of water works materials and equipment. Several cities are now using new products as soon as they are developed, on a test basis, the result of the tests being carefully recorded. The funneling of this information to a central point in the Association would be helpful in determining the adequacy of the product, and the assembling of the operating data would be valuable

in preparing standards for such a product.

Water works men should reject low-grade or inferior materials supplied under an AWWA standard and report to the Association when satisfactory adjustments are not made by the manufacturer. By rejection of inferior goods, a fund of information will be gathered regarding those products, and the manufacturers of high-grade materials will be in a better position to sell their products when purchases are made by competitive bidding.

It is recommended that the name, home town, and affiliation of those attending appear on the identification badge at conventions. It is also recommended that the identifying badge be worn on the right coat lapel instead of the left coat lapel, to make it easier for those meeting to read the badge.

It is recommended that manufacturers be represented on the executive board of each of the Sections. At present, in most Sections, the manufacturers have no voice in the conduct of Section affairs. This action has already been taken at the Association level and in some of the Sections. To be eligible for appointment to the board, a manufacturer's representative should be a member in his own name.

AWWA should take a more active and aggressive part in the preparation of international standards.

5. Large Water Utilities

No report was received from this subcommittee.

6. Small Water Utilities

The small utility should be defined as one serving 5,000 customers or less. Utilities with more than 5,000 customers generally are in a position to secure and pay for help when they need it, although no rigid line can be drawn.

One of the biggest problems is that very few of the small operators are members of the Association, and therefore most are not within the present influence of the Association. In Mississippi, for example, there are about 285 communities, practically all of which have a water system of some kind. Yet from this group, it is quite safe to say that fewer than 50 (very likely much fewer) have membership in the Association.

It is also evident from the reports filed by the members of the subcommittee that we are in agreement on the fact that in most instances the person responsible for the water system in this class is not in any way trained in education or experience for the work and quite often has a dual duty serving as marshal, city clerk, police chief, or in some other function. In this regard, we are all in agreement that very little of the responsibility for the situation can be laid at the door of the operator, since in most of these small communities the elected officials are not aware of the problems involved and are intensely aware of any money that is spent.

If Mississippi is even a 50 per cent measure of the entire United States, the AWWA membership of approximately 13,000 would indicate that there are at least that many, and probably five times that many, small water works operators who are not members of the Association and do not receive any benefit of its help.

From our knowledge of the small water works operator, we are convinced that in most instances they are completely isolated from other water

works operators because their boards and other responsibilities limit such associations. The result is that they quite often buy things they do not need and never use, they have no real means of determining the best device for the purpose needed, are fair prey for crooked tank painters and repairers, and have very little knowledge with which they can influence their board toward improvements. Their knowledge of management is limited or nonexistent, as is their knowledge of any thing approaching technical considerations for water systems.

Where treatment is necessary by small systems, it is thought that most governing boards are more willing to utilize better qualified personnel.

Steps for Consideration

With the foregoing in mind, the cochairmen of the subcommittee make the following recommendations for consideration by the Association:

1. *Make a determined and considered drive for membership from the small operators.* We do not know the answer to this one because we have tried so hard in our respective states, but there must be some way that membership in the Association can be made attractive, either through the municipal boards or the individuals themselves.

2. *Redesign the AWWA publications toward a handbook and how-to-do-it type of publication,* particularly designed for the small operator and perhaps insert a section into the JOURNAL or *Willing Water* publication designed particularly for the small operator.

The Mississippi operators are planning a water works school in February with this basic idea in mind, and it is hoped that the result will be a reference handbook type of literature to give to the operators attending. This handbook will cover management as well as operating items.

Another thought is that some of the publications in the electric field have developed this plan to a very high degree, such as the *Power* magazine.

3. *Send a questionnaire to the subscribers of the Journal to get their viewpoints on the present Journal and thoughts on suggested changes.* As stated before, it is the opinion of at least one of the cochairmen that the present JOURNAL serves no useful purpose to the small operator and is a waste of paper. On the other hand, those operators who have treatment plants seem to find the JOURNAL very interesting. In our opinion, the JOURNAL is written at a level much too high for the small operator with whom we are concerned. The questionnaire might develop some excellent ideas on possible changes.

4. *Actively promote and assist sections or states on water works schools.* Again in the case of Mississippi, this burden falls on a very few water works men who are in a position to do anything about the school. We secured no help from any other agency except the state university, and it is quite a burden. If AWWA could assist by studying the results of successful schools and make this information available to some states that are just starting, or if it had a committee whose purpose would be to design the best possible school curricula, then something definite would be contributed in this category.

5. *Consider a limited or subscription membership for the handbook and how-to-do-it publications.* It is thought that if this could be placed in the hands

of small operators whom we cannot now get interested in membership, it would eventually lead to membership in the Association after it has served to help them in their work. The small water works operator who joins the Association now and gets a monthly magazine which he does not understand and gets no benefit from naturally wonders what he gets for his membership dues. Possibly a more limited fee that would barely cover the cost of printing would help some of these men to get some benefit from the Association prior to actual membership and if the benefit is actually received, they should be much more interested in membership in the Association.

6. *Provide a simple bookkeeping system for a small water works operator.* To most small businessmen, such as plumbers and electricians, their national associations offers for outright purchase a very simple system of bookkeeping that almost anyone can operate. The system includes specific instructions on how to do the job and it does not require a certified public accountant to handle it. It may be that such a system could be worked out for the small water works operator to the point where, with the limited information that he usually has, he can produce a few simple items that would tell him where his system is headed.

7. *Plan a nationwide publicity campaign* through media that cover small communities, that will lead the citizens to give thought to their water system.

It is our opinion that the material suggested above should be limited to a high school education level and that it should be as nearly nontechnical as possible. This means it will be composed principally of rule-of-thumb types of information, as, for example:

a. A 2-in. water line at 60 psi pressure will adequately serve ten average homes for a distance of 500 ft.

b. Two 3-in. lines equal one 4-in. line; two 4-in. lines equal one 6-in. line; two 6-in. lines equal one 8-in. line, etc.

c. A double feed for one 6-in. line gives the equivalent of one end-fed 8-in. line.

d. Water meter sizes should be based on consumption rather than pipe size.

e. A simple guide on purchasing of equipment and accessories that will help the small water works operator in selecting such things as curb stops, corporation stops, cast-iron or asbestos-cement pipe, and the like—possibly a simple buyers' guide type of publication.

Conclusion

How to do this is the best question of all because if it were easy to handle, it would have been done long ago.

In our opinion, however, a large water works operator cannot possibly understand the problems of the small water works operator with whom we are concerned here. Therefore, the work must be done by men who are in the upper echelons of the small water works operator's bracket, ranging in the 5,000–10,000-meter class.

The only possible suggestion we have is to formulate a national committee composed of such operators, carefully selected with the viewpoint in mind that they will have to meet regularly for so long as it takes to develop the information, and periodically thereafter to keep the program going. They should be in such a position that their boards will stand the expense of the traveling and other such costs, or AWWA should provide it.

We do not think there will be any applications for these jobs from anyone we know, so somebody will have the job of selling them on doing the job.

7. Public Health

It is the consensus of the members of this subcommittee that AWWA is presently doing an outstanding job for its members. Public health topics are well dispensed throughout the JOURNAL, *Willing Water,* and the convention programs. Committee reports, standards, and other materials made available by the Association are very valuable references.

Current Activities

Our suggestions and recommendations are intended to be of a constructive nature, as we have no major criticism of the present aims and objectives of the Association.

The Journal and Willing Water. The public health subcommittee is generally satisfied with these publications as they are. Consideration might be given to including a new section in the JOURNAL devoted to research activities, either in the form of a tabulation of current projects or brief summaries of work in progress. The Purification Division might assist in this through formation of a special committee with the responsibility of regularly supplying information on research activities in the form of news items and summaries.

Space in the JOURNAL might be allocated to the various Divisions with assignment of appropriate editorial responsibilities. It is also suggested that a more frequent listing of currently available AWWA manuals, reprints, committee reports, and other similar material in *Willing Water* or the JOURNAL would be useful.

Manuals. The AWWA manual, "A Training Course in Water Utility Management," is a very worthwhile and useful publication. We recommend that present efforts be accelerated in the development of a series of training manuals in all the various fields of water works practice, especially in water treatment.

Research activities. As pointed out by Faber, Larson, and Jordan in the November 1959 issue of *Willing Water,* there is no question about the need for an organized program of both basic and applied research in the water utility field, but there is a question as to the extent of such a program and how it would be carried out, especially with regard to AWWA activities.

It appears that there are at least three possible degrees of additional participation by AWWA in research:

1. AWWA might provide the direction and develop the support for an adequate long-range program of research, with most or all of the actual research work being done by state and private universities, USPHS, and other private and governmental organizations already equipped and staffed for this purpose. For example, AWWA might stimulate interest in specific subjects such as viruses in water, the effects of insecticides, herbicides, and other organic chemicals in water, the reuse of water, or other problems of interest to its members by a series of articles in *Willing Water* or the JOURNAL. Or, by acting as a clearinghouse for information on water research, AWWA could point out the gaps in the work being done, eliminate unnecessary duplication of effort, and be in a position to give advice and consultation. There are, of course, many other ways that AWWA could exert leadership and provide guidance in this field. This sort of a program might be accomplished within the existing framework

of AWWA, with only small additions to its office staff.

2. To go further, if there is research of vital concern to AWWA members which cannot be initiated through existing channels, perhaps AWWA could finance projects on a contract basis with existing research organizations. This might require changes in the AWWA Constitution and Bylaws.

3. A third possibility would be for AWWA to change its Constitution and Bylaws to permit it to receive and expend funds for the actual conduct of research by AWWA. This, of course, would be quite an ambitious undertaking in terms of organization, staff, physical facilities, and money.

If AWWA conducts its own research on public health aspects of water supplies, it should do so in consultation with the health and regulatory agencies, so that the results will be acceptable for incorporation into administrative practices for the protection of water supplies. If AWWA is to give increased emphasis to research, a decision on how far to go would seem to rest on the relative importance of research with respect to other AWWA activities; the desires of its membership in this regard; financial considerations; and how AWWA can contribute most to overall progress in water-related research, whether by active participation or by providing leadership and stimulus.

Divisional activities. Because the chemical quality of water supply sources and the effect of pollution have such a direct relationship to water treatment practices and problems and are becoming of such increasing importance, it is suggested that the name of the Water Purification Division might be changed to recognize this development. It might be called the "Water Quality and Purification Division" or something along this line, with appropriate added responsibilities being assigned to the Division in accordance with changes which have occurred in this area.

While we think it is desirable and essential that the Distribution Division and the Purification Division engage in activities which develop information on and establish general criteria relating to pumping capacity, purification, storage capacity, and distribution with respect to present and future population and water usage demands, we recommend that no specific detailed minimum water works design standards be adopted by AWWA, as this is properly within the province of state agencies and other official governmental regulatory bodies having statutory responsibilities in this regard.

Likewise, the Purification Division might very well establish a system of grading water quality, bearing in mind the revised USPHS drinking water standards. Although the USPHS standards generally specify only minimum requirements, they do recommend as desirable certain quality characteristics beyond what is required for health protection. Accordingly, the USPHS standards may be considered as a part of the proposed AWWA grading system. The latter should, however, rate not only the supply but the facilities as well—for example, the adequacy of treatment to maintain consistently high quality water. A system of rating water supplies and works should offer deserved recognition for cities and companies which provide above-average facilities and for operators who do a high-quality job.

Committee activities. Consideration might be given to the formation of a task group on insecticides, herbicides,

fertilizers, and miscellaneous organic chemicals in water with a view to determining the extent of the pollution problems arising from the use of these materials.

Convention programs. The consensus of the subcommittee appears to be that these meetings are satisfactory as currently presented. In view of the magnitude of these programs, it is recommended that close liaison between Divisions be maintained and an effort be made to develop more joint Division sessions.

Legislative activities. If AWWA does not already maintain a file of all state and federal laws pertaining to water, especially water rights and pollution abatement laws, this would be a worthy endeavor.

In many states there is an increasingly keen competition between public water supply use and heavy consumptive use for irrigation. Unreasonable consumptive uses can seriously deplete a water source to the point that it jeopardizes public water supply use and the quantity of dilution water available for the assimilation of even highly treated domestic and industrial wastes. In an effort to develop comprehensive recommendations regarding needs for management of water quality and quantity, close liaison is desirable between AWWA and WPCF. It may be desirable for AWWA to make specific recommendations and represent the water utility field in hearings on federal legislation. AWWA should take the necessary action to join WPCF in such representations and also to develop the necessary factual information to justify its position. Federal construction and health agencies are currently studying municipal water needs and are planning to include them in recommendations for future resource development projects. AWWA could, with good factual information, strongly support a position to include in these projects storage to provide for future municipal water supply. This activity probably would not require any major changes in AWWA staff or organization, but merely a closer coordination between two associations having a common interest in the adequacy of water resources.

AWWA might very well follow the example set by the State and Territorial Health Officers who adopted a resolution in 1959 recommending that the statutory authority for state water supply and water pollution control programs remain with state health agencies and that action be taken to oppose the transfer of water supply and pollution control authority from public health agencies to other agencies.

New Programs

The subcommittee suggests that AWWA sponsor a nationwide survey of persons who are trained in water utility operation, management, research, and other related fields, and that a current file of this information be maintained. It is recommended that AWWA, through its committee on certification and training, establish recommended minimum qualifications for people who work in water treatment plants and that these job specifications be made readily available to employers.

In its program of public information on water supply matters, AWWA should not overlook the education of schoolchildren. As one facet of this, the committee on education might review the material contained in school health and science textbooks and make comments and suggestions for improve-

ment to the publishers, authors, and educators. Most of these textbooks are sadly out of date, inaccurate, and incomplete. If the Association expands its certification program in the water works equipment field, it is suggested that approval of the public health aspects of materials be checked and coordinated with the Conference of State Sanitary Engineers as well as USPHS. If AWWA does not itself establish laboratories for scientific investigation of products and equipment marketed for use in the water works field, the Association might work toward the establishment of such facilities by others.

8. Research

It is proposed to establish a "Water Research Institute" as an independent nonprofit corporation in affiliation with AWWA. A suggested proposal is submitted below.

Objectives

The objectives of the corporation shall be to contribute to the present and future progress of the water supply industry, and inherently to the public good, by developing a constructive and collective research program, and by providing methods of receiving and administering dues, contributions, gifts, and grants-in-aid for the support of the research program.

Purposes

The Water Research Institute shall be organized under articles of incorporation designed to accomplish the following purposes:

To promote the stated objectives by encouraging, supporting, and conducting research and scientific investigations in the fields of water resources, transmission, processing, distribution, and management, and by acquiring and disseminating knowledge in relation thereto.

To receive or acquire by devise, gifts, or otherwise any money or property, either absolute or in trust to be used, either the principal or income therefrom, as may be directed, for the furtherance of any of the purposes which may be within its corporate powers.

To purchase, sell, or lease property, real, personal, or mixed, for the benefit of the Institute.

To create, purchase, hold, and sell patent rights in the interest of the public welfare for inventions, designs, and copyrights, with the right to issue licenses for the exercise of rights relative to said inventions, designs, and copyrights, and to receive payments therefrom and to use and apply all moneys thus received for the fostering and advancement of research and scientific investigations.

Organization

The Institute shall consist of affiliate members and sustaining members. Affiliate members shall be the American Water Works Association and others as may be designated by the board of trustees. Sustaining members shall be any qualified public or private water utility, firm, or corporation, or any qualified organization or individual interested in supporting the objectives of the corporation, subject to approval by the board of trustees.

The affairs of the Institute shall be managed by a board of trustees elected as representatives of the sustaining members of the Institute.

The board of trustees shall have the power to hold and conduct meetings at

times and places as it may think proper, to make policy decisions, to admit members, and to collect and disburse the funds of the Institute.

Officers

A president and vice-president shall be elected from the membership of the board of trustees, to perform the duties necessary to these offices.

A secretary-director and a treasurer shall be appointed by the board of trustees. The offices of secretary-director and treasurer may be held by the same person. The salaries of appointed officers shall be determined by the board of trustees.

Operations

The operation of the Institute to promote the stated research and scientific investigations shall be the duty of the secretary-director. The operations include responsibilities for providing secretarial services and maintaining communications between the board of trustees, the executive council, and the advisory council. The operations also include responsibilities for administration of the actions and plans of the executive council.

The executive council shall consist of twelve members, comprising six elected representatives of the sustaining members of the Institute, one elected representative of each Division of AWWA, the Executive Secretary of AWWA, and the manager of WSWMA. The executive council shall meet biennially or more often as necessary and shall elect a chairman and vice-chairman from its membership.

The executive council shall, after consideration of the recommendations of the advisory council, determine the appropriate action on all grants or contractual arrangements for research and scientific investigations. The executive council also shall have the responsibility for developing long-range planning for the research and scientific investigations of the Institute.

The advisory council of the Institute shall consist of members appointed by the executive council from individuals proposed by the secretary-director and approved by the advisory council. Its membership shall be composed of nationally recognized research authorities, with at least one representative in the fields of geology, engineering, chemistry, bacteriology, biology, public health, and management.

The advisory council shall determine the scientific merit of all grants or contractual investigations submitted to it, and shall have the responsibility of assisting the secretary-director in preparing his recommendations to the executive council.

Committees may be appointed by the executive council at the request of the secretary-director to assist in special purposes as may be necessary.

9. Section Secretaries

The subcommittee reports as follows:

Publications

The subcommittee feels that a special edition of *Willing Water* should be published quarterly containing data and information of particular interest to small water works operations, and that a publication of this type would engender new interest in membership in the Association on the part of small plant operators. It is recommended that consideration be given to this matter by the general committee.

One of the Section secretaries has called particular attention to the fact

that *Standard Methods* was once a very useful tool for the average water, sewage, public health, or commercial-laboratory technician, but that in recent years this publication has become more and more complex until, as it is presently published, it no longer serves the purpose for which it was originally intended. The committee member points out that in many respects the present edition prescribes tests which are far beyond the ability of many water and sewage plant laboratories to perform, either from the standpoint of personnel or equipment, and that perhaps a second manual of more practical application, which would help the average laboratory technician, should be prepared. [Such a manual is under development.—*Editor*]

If the recommendation regarding the publication of a special edition of *Willing Water* for small plant operators is favorably considered by the general committee, possibly some simplified procedures or methods of examination could be included as part of the data and information to be published in such a *Willing Water* edition.

Section Management

The subcommittee is unanimous in its opinion that the various Sections should continue to be autonomous, insofar as internal management is concerned, within the present prescribed limitations of the AWWA Constitution and Bylaws.

It has been suggested by one of the committee members that consideration could be given to revision of Article 8, Sec. 11 of the Bylaws, which reads: "Any Section or Division may be dissolved by the Board of Directors for reasons which it believes to be sufficient." The member raising this question believes it might be advisable to revise this section of the Bylaws by adding thereto: "only after review of the action with the board of trustees of the local Section or Division."

Consideration was given by the committee to revision of the existing manuals of procedure to be followed as a general guide by Section officers, which include a director's manual, a chairman's manual, and a secretary's manual. There was a division of opinion on this matter, but a sufficient number of the committee members deemed such a revision to be advisable to the degree that separate committees of Section directors, chairmen, and secretaries should be established for this purpose to work in cooperation with the AWWA staff. A recommendation to that effect is submitted for consideration by the general committee.

The majority of the committee feels that each Section should include on its executive committee one Section member who also represents a member of the Water and Sewage Works Manufacturers Association. A recommendation to that effect is hereby made for consideration by the general committee.

It was the unanimous opinion of the members of the committee that adequate consideration is now given to the selection of dates for Section meetings so that they do not interfere with other Section meetings in the same general geographic area. Therefore, no recommendation is made concerning this matter.

Finances

The majority of the committee feels that the new AWWA allotment is sufficient to carry out presently required and expanded Section activities. How-

ever, the feeling of one member is that the smaller Sections do not receive a sufficient allotment. This Section advises that it must make up out of its separate registration funds each year a deficit incurred; the Section has to rely a great deal on voluntary services, with part of the expense being borne by the agency by which the secretary is employed. This has been true since the formation of the Section.

Some consideration should be given to raising the minimum allotment from the present $200. In this connection, it is of interest to note that two Sections (Cuban and Montana) had 1960 entitlements of $200, three additional sections (Arizona, Intermountain, and West Virginia) had 1960 entitlements of less than $300, and one Section (Nebraska) had a 1960 entitlement of $322. All other sections have 1960 entitlements in excess of $500. The smaller sections might be afforded a minimum allotment which would at least equal the basic expenditures of the type that are authorized to be incurred from the allotment.

The annual increase in cost to the Association would be $1,440 to raise the minimum entitlement to $500. The total expenditure would increase from $33,276 to $34,716, an annual rate of increase of 4.3 per cent, and the five smallest Sections would benefit appreciably by such a change in entitlement. An increase to $500 is therefore recommended.

With regard to the items of expense which the Sections are permitted to charge against the AWWA allotment, a majority of the committee members are satisfied with present practice. However, one of the points raised in connection with such chargeable items is the payment of the expenses of the Section secretaries to the annual AWWA conference. The feeling is that the secretaries should be recognized as a part of the Association and that expenses incurred in attending the conference should be chargeable to the AWWA allotment.

Another point considered was whether the Sections should automatically grant the permissible honorarium to the secretaries (an amount not to exceed one-third of the allotment). The granting of the honorarium is optional with the Sections and only eleven now do so. There was an equal division of opinion among committee members on this subject, one-third being in favor, one-third opposed, and one-third for allowing the matter to remain optional with the Section.

It is, therefore, recommended that honorariums remain optional with the Sections, but further recommended that, in lieu of the honorarium, any Section may permit its secretary to attend the annual conference of the Association and defray the expenses incurred in an amount equal to the permissible honorarium.

At the present time Section secretaries are generally required to submit two separate annual financial reports to AWWA, one at the close of business on Nov. 30 each year and another at the time of the annual meeting of the Section. The committee is satisfied with this arrangement and makes no recommendation for changing it.

On the question of double registration fees for nonmembers of the Association attending Section meetings, the committee is unanimously opposed. It is also opposed to collecting additional separate registration fees at Section meetings from consulting engineers and other professional persons

engaged in private practice in the water works field.

The Section secretary is now required to maintain a breakdown of receipts of registration fees as to the type of registrant—that is Active Member, guest, Associate Member, representative, representative of nonmember manufacturers, and others—for submission with the AWWA annual financial report. The majority of the committee feels that this requirement should be eliminated because of the difficulty of furnishing accurate data in this respect, especially in relation to Associate Member representatives and representatives of nonmember manufacturers. Registrants at Section meetings are not generally required to provide such information on the registration cards, and it is difficult and time consuming for the secretary to divide the registrants into the various categories. It is therefore the recommendation of the committee that this requirement be eliminated.

Section Meeting Papers

The question of requiring the submission of manuscripts prior to presentation of papers at section meetings was considered. The majority of the committee felt that this should not be required, although others thought it should be required but would be difficult to obtain. If such a requirement were made, there probably would be more manuscripts prepared for submission to AWWA for consideration for publication in the JOURNAL, but no recommendation is made concerning this matter.

It was ascertained from committee members that the number of papers forwarded to AWWA for consideration varies from a minimum of 30 per cent to a maximum of 90 per cent, with an average of approximately 55 per cent. It was felt that, if some formal procedure could be followed by the various Sections, a higher percentage of the papers delivered at Section meetings might be available to AWWA. Therefore, while the committee has no recommendation to make concerning this matter, it seems to deserve further consideration by the general committee, with possible reference of the matter to the AWWA staff.

Membership Promotion

The committee agreed that successful membership promotion could be best obtained by personal contact with prospective members, and several of the committee felt that a system of awards for securing new members would be an added incentive in this respect. Another matter considered was the preparation of a list of prospective members for use by the Section membership committee. The majority of the committee felt that the entire membership committee should prepare a list of prospective members. Several members of the committee suggested that this should be done as a cooperative effort between the Section secretary and the entire membership committee. While there does not seem to be any necessity for a definite recommendation in this respect, it seems advisable for each Section, through its membership committee and the Section secretary, to prepare a list of prospective members within the Section territory, the list to be made available to all members of the committee.

There was quite a decided difference of opinion as to the time that new members (except Associate Members) should be added to the roster of the Section. A number of the committee members feel that the Section should be privileged to add the name of a new member to its tentative rolls upon re-

ceipt of an application from the member, while an almost equal number felt that new members should not be added to the roster until after final notification by the AWWA membership department that the applicant had been approved by the Committee on Admissions. No recommendation is made by the subcommittee concerning this matter because of the almost equal division of viewpoint concerning this item.

Safety Program

In relation to the safety program, one question considered was who in the Section should be responsible for preparation of a list of members eligible for safety awards. It was almost the unanimous opinion of the committee that the chairman of the safety committee should have this responsibility.

The members of the committee report that the percentage of eligible members submitting safety records varies from a low of 25 to a high of 75, with the average being approximately 60 per cent. It is felt that better participation can only be fostered by continuation of the program with an active safety committee and chairman and with the continuation of the safety awards as now practiced. The percentage participation in the program will increase in time with perseverance by the safety committee and education of the membership about the program.

Advancement Program

It is the opinion of the majority of the committee that distribution of the *Willing Water* advancement quarterly should be handled by the chairman of the Section advancement committee.

Summary

1. A special edition of *Willing Water* should be published quarterly containing data and information particularly related to small water works operations.

2. The various Sections should continue to be autonomous insofar as internal management is concerned within the prescribed limitation of the AWWA Constitution and Bylaws.

3. It is suggested that Article 8, Sec. 11 of the Bylaws be revised by the addition of the following phrase: "only after review of the action with the board of trustees of the local Section or Division."

4. Separate committees of Section directors, chairmen, and secretaries should be established to cooperate with the AWWA staff in the revision of manuals of procedure for these officers.

5. Each section should include on its executive committee a Section member who also represents a member of the Water and Sewage Works Manufacturers Association.

6. Consideration should be given to an increase in the minimum AWWA allotment to those Sections now receiving less than $500 a year.

7. The granting of an honorarium to the Section secretary should remain optional with the various Sections, but in lieu of granting such an honorarium, any Section should be permitted to defray the expenses of the secretary at annual AWWA conferences in an amount equal to the permissible honorarium.

8. Separate registration fees from consulting engineers and other professional persons should not be required at Section meetings.

9. Double registration fees from nonmembers of the Association should not be required at Section meetings.

10. Section secretaries should not be required to submit a breakdown of registration fees in accordance with the type of registrant as a part of the annual financial report.

TABLE 1

Survey of Section Officers on Service to Members

Existing Programs	Continue as Usual	Expand	Priority of Importance	New Programs Yes	New Programs No
1. Safety	59	19	A		
2. Accounting					
AWWA standards	56	8			
PUC standards	56	6			
3. Awards & contests	62	6			
4. Publications					
Journal	60	10			
Willing Water	65	11			
Standards	58	21	A		
Committee reports	60	14			
Manuals	56	19	A		
5. Committee and Division activities					
Divisions	54	12			
Professional & Administrative Practice	50	14			
Standardization	50	15			
New Programs					
1. Exhibits & shows at Section meetings	8	3		30	35
2. Education					
Set up more seminars in Sections in management, research, etc.	13	12	A	47	6
Set up clearinghouse for ideas on other fields, i.e., research, management, etc.	12	9		40	5
3. Research					
Task groups covering all phases, including management	8	16	A	36	13
Set up an operation like Lawrence Experiment Station	4	6		19	25
4. Employee-employer relations					
Publish various union agreements	2	6		34	19
Fringe benefits	1	7		37	19
Publish periodically salary surveys of all classifications	0	9		40	14
AWWA support to local water works officials where needed and justified	0	7		39	14
Pension plans	1	7		42	9
5. Exchange services (interchange of information with other societies)	4	12	A	50	3
6. Expert services (should AWWA provide staff for above, covering all subjects about which AWWA would publish reports, including legal, rate making, labor relations, etc.)	2	10		38	14
7. Insurance (group plan)					
Life	1	2		23	34
Health	1	2		14	37
8. Library service (should AWWA furnish reference lists of written and filmed subjects)	0	12	A	57	4
9. Employment service (AWWA to serve as clearinghouse)	0	12	A	49	12

11. Further consideration should be given by the general committee and the staff to the matter of preparation and submission of formal papers presented at Section meetings to the AWWA office for consideration for publication.

12. Each year the Section membership committee, in cooperation with the secretary, should prepare a list of prospective members for the use of committee members.

13. Each year the chairman of the Section safety committee should prepare a list of members eligible for safety awards and transmit safety report forms to eligible members only.

14. The distribution of the *Willing Water* advancement quarterly should generally be handled by the chairman of the Section's advancement committee.

10. Service to Members

Since this subcommittee was formed, the chairman wishes to state that we held one formal group meeting at the San Francisco convention in 1959, and since that time there has been but one meeting between the cochairman and myself, but correspondence has been exchanged.

The committee agreed that a checkoff sheet should be designed to get a poll of the officers in all AWWA Sections. The checkoff sheet covered five existing programs which we felt were most beneficial to individual members and also suggested nine new programs. This questionnaire was sent to all our committee members and they, in turn, covered the chairman, vice-chairman, secretary, and membership committee secretary of the Sections which had been assigned to them. I am not sure whether or not we have received through their Section officers the full impact of the ideas of the general membership on services to members. However, I do feel that we have fair representation from the 80 checkoff sheets received out of 124 sent out.

The results of this survey are shown in Table 1. In reviewing these 80 returns, it was evident that there was some degree of confusion as to how to fill out the sheet; however, I believe definite patterns come out of it. All of the five existing programs received a complete vote of confidence, and it could be said that three programs should be expanded—safety, standards, and manuals. I would say that these are all of equal importance and should be given the same priority.

In regard to the new programs, some people checked off the two columns that were set up for existing programs. This, of course, was in error, but at least it would indicate that they were in favor of the new program and possibly thought it was existing.

The "Yes" and "No" columns under "New Programs" certainly point out that two suggestions do not meet with general favor—exhibits and shows at Section meetings, and life and health insurance. The rest of the nine suggested programs meet with varying degrees of favor, and I would suggest that the ratio of "Yes" to "No" would be indicative of the priority with which the new programs should be considered.

It is interesting to note that, under Item 3—Research, the general opinion was to have a new program, but a separate operation such as the Lawrence Experiment Station was voted down. I have found that not too many people know exactly what the Lawrence Experiment Station does, and they were worried about how such a program could be financed; I would suspect that this is one reason why it did not meet with too much favor.

The Section officers were invited to make any comment they desired in

addition to filling out the checkoff sheet. I urged that they advise us of any special programs in the Sections that had been very popular and of particular service to their members. The following are some of the comments made by committee members which were picked up from checkoff sheets:

Iowa Section has many active committees making regular surveys on salaries, rates, main extension practices. This has proved to be popular among the members of the Section.

A review of the method of awarding the Henshaw Cup is in order. [The terms of this award have been changed, effective in 1961.—*Editor*]

An education program should be set up for management and research.

Section meeting round-table discussions are particularly popular and reach the small utility operator.

More education of city council members and the like is desirable.

More manuals, updating the existing manuals and standards, more research, more education programs are needed. [These items were stressed by a great number of committee members.]

Seminars and regional meetings within the Sections for management and operation of water plants should be created.

From my many contacts while making this survey, I am of the opinion that by and large the Sections generally do very little work between their annual meetings. It seems that they have varying committees within the Section —some probably set up at the suggestion of AWWA headquarters—but there is actually very little work accomplished during the year. It is my opinion that if more educational regional meetings are set up within the sectional organization, we will build a stronger and more closely knit Association. The members would get direct benefits from such meetings and once established they would become extremely popular.

It is pertinent to note that in western Kentucky a new organization has recently been formed for water and sewage operators. This group meets regularly every 3 months and embodies plant visitations in its program to get down to the grass roots. It would appear to me that this AWWA Section has not been giving service to its members if a region within the Section must create another new organization! The AWWA Section should recognize this deficiency and do something about it. In Pennsylvania, we have a number of water utility organizations, and I believe this is basically because the AWWA Section has rarely come up with good programs or active committees to keep real interest among its members. Therefore, I would recommend that the Sections be put to work to give service to members.

As chairman of this subcommittee, I would recommend that it be kept intact to make further surveys. It is my thought that every Section should allocate at least 15 min on its annual program for a session on "Service to Members." AWWA officers, who attend practically all these meetings, could promote comments from the Section officers, as well as the membership, and this committee should receive a report from the Section secretary on this phase of the program. After a year, the committee could certainly compile a very accurate report, possibly one much more comprehensive than at present.

I believe also that it would be of interest for this committee to investigate what services other organizations of similar size are giving to their

members, with the ultimate thought of our being able to provide more and better services which will build our organization.

11. Water Quality and Treatment

Though all the committee members commented on the appropriate portions of the work assigned to them, there was virtual unanimity in the belief that AWWA is paying too little attention to the subject of water quality. This applies to both raw and treated waters.

This committee's feeling is that water quality considerations are taking a back seat to many other activities that the Association is carrying on, and are being precluded from having as much space as they should have. It is the belief of this committee that there is no more important topic on the Association's agenda and that it should receive continuing major emphasis.

Research

The members were substantially unanimous in agreeing with Harry Faber's views. We think AWWA needs a full-time research director with a well qualified technical assistant. These men should be aided by a special research board of 7–10 members having high qualifications. It would be the job of this group to bring about a manifold increase in research activities in federal agencies, state organizations, universities, and municipalities, and to help coordinate this research.

The AWWA research organization should be supported by grants from institutions, and by such methods as subscriptions from consultants and utilities (based on gallonage). The research group should collect, coordinate, and disseminate the results of the research work far more widely than now. Our committee has many suggestions on topics for research.

Conference Programs

The members of this subcommittee were quite unanimous in feeling that the AWWA conferences are not well handled so far as the management and content of sessions go. Programs are too crowded, and too little time is allowed for discussions from the floor. Too much detail is given verbally in presentations, there are too many conflicts between program events and simultaneous committee meetings on similar topics, and there should be improvement in the advance planning.

We think that much needs to be done to improve the interest and presentation of the programs if they are to attract attendance and serve their purpose. Possibly this can better be done by setting up clear procedures for program planning, with preannounced deadlines and assigned responsibilities to Division officers and others, and by setting up a new format on presentation of papers which will require authors to write a short presentation separate from their papers for publication, thus permitting adequate discussion time to be allowed.

New Committee Activities

We believe there is need for a number of additional committee activities, prominent among which are:

A committee to assemble and disseminate information on waterborne virus diseases.

A committee on utility insurance, set up jointly with WPCF.

Additional data from Committee 4140 M on fire demands, relating to metering, connection sizes, and sprinkler needs.

Committee 4230 M should present its compensation data on a regional basis.

Committee 4420 M should gather much more widespread data on water rates, to be published annually in a yearbook.

Utility Personnel

The members of this committee are disturbed about the declining quality of technical personnel in water utility operation. We think this subject needs to be emphasized in many ways. All personnel should be encouraged to attend meetings and take special school courses where available, and in-service training should be promoted. This needs to be plugged in *Willing Water* and in many other ways.

Efforts to improve the status of water works personnel through certification (in coordination with WPCF), higher pay rates, public relations, and any other means at our command should be expanded, for qualified personnel with the necessary interest and abilities are required if our industry is to advance and keep up with the needs of this advancing world.

12. Publications

This subcommittee considers that the aims and objectives of the American Water Works Association are: (1) to provide useful information and assistance to its members; and (2) to enhance and uplift the professional standing of its members. Suggestions by this subcommittee, aimed particularly at Item 2, are as follows:

That the Association create conditions, particularly at its various sectional meetings and its annual conference, that will encourage the press, radio, and television media to look to these meetings as a possible source of news and features. This probably would entail the use of a public relations man at these meetings to assist the reporters.

That any member of the press be privileged to register at these meetings freely and without charge. If a registration fee is involved, in general a reporter will avoid the meeting for understandable reasons. If the Association still wishes to require a registration fee from the representatives of the "technical press," they will not object and undoubtedly will cover these meetings anyway. It is strongly suggested that press, radio, and television representatives also be given complimentary tickets to luncheon and dinner events, if they choose to attend. Here again an exception of the "technical press" may be made.

That a greater effort be made to have the papers prepared in advance of the meeting so that mimeographed copies can be made available to the press, and also that useful summaries be provided. Some sort of press facilities should be made available also.

That for the annual conference a preconvention cocktail party and an inspection, particularly of the exhibits, be provided for members of the press in the city in which the conference is being held. This will furnish information for subsequent stories. It is strongly suggested also that those who are going to deliver papers be made available for interview at that time.

That AWWA consider setting aside 5–10 per cent of its annual operating budget for advertising and promotion so that an organization can be established on a continuing basis to make this into a workmanlike program.

That news releases report the activities of each man who prepares a paper at local Section meetings and at the annual conference, and also of any man who wins an honor or otherwise dis-

tinguishes himself at these meetings, so that they may be forwarded to the paper of his home town.

That AWWA strive to provide active cooperation with such groups as the American Municipal Association, the US Conference of Mayors, and the International City Managers' Association, offering to prepare useful papers for their meetings if desired and assigning some of their most competent members to these tasks if the invitation is accepted. Members of AWWA who have demonstrated leadership and outstanding ability should be asked to attend these meetings to represent AWWA's interests.

13. Finances

The Subcommittee on Finances was appointed at the conclusion of the Annual Conference at Bal Harbour in May 1960. The function of the subcommittee is to study, appraise, and recommend ways and means of financing the recommendations of the other subcommittees.

Recommendations

1. That the Board of Directors define and outline in detail the new program for the Association contingent upon approval of Recommendation 2 below.

2. That Schedule 3 of Table 2 proposing increased dues in the amount of $598,000 be adopted as the basic plan for increased revenues by the Association in 1962, to be modified as necessary to meet actual cash requirements.

3. That, on a voluntary basis, increased advance dues be collected in 1951 based on Schedule 3. That portion of the increased advance dues paid over and beyond the present dues by Corporate Members and Associate Members in 1961 shall be used immediately for the employment of an association consultant or association management group to:

a. Review in detail the dues that are being recommended by this subcommittee in a general way, to be certain that all categories are correctly covered, the block rates as recommended are uniform and practical, and clarification of exceptions to the scheduled fees is made.

b. Examine all classes of revenue presently received by AWWA to determine if, through new methods and procedures or through new promotional efforts, the revenues can be increased.

c. Assist in the implementation and follow through on the program to be recommended by the Aims and Objectives Committee.

4. That, as a test project, a man be employed by AWWA and put in the field to sell the new program and membership contemplated herein, this to be done in a populous area where it appears that such a project would benefit the Association financially.

5. A public information bureau be considered by the management consultant and others and be established immediately for the purpose of disseminating information throughout the country to acquaint water utility governing bodies that are not presently members of AWWA with the benefits and information that can be secured from this organization, thereby increasing the potential for dues from the present membership as well as from nonmembers.

Recommendation 1

In the original meeting of the Subcommittee on Finances, the committee determined that it would make no recommendations which were outside of the responsibilities of the committee,

TABLE 2

Alternative Plans for Increasing Operating Income

Item and Action	1960 Budget Income $	Schedule 1 Pro-posed Income $	Schedule 1 Net Increase $	Schedule 2 Pro-posed Income $	Schedule 2 Net Increase $	Schedule 3 Pro-posed Income $	Schedule 3 Net Increase $	Schedule 4 Pro-posed Income $	Schedule 4 Net Increase $
1. Advertising—increase rates 20%	150,000	180,000	30,000	180,000	30,000	180,000	30,000	180,000	30,000
2. Publication sales—increase annual income $50,000 at rate of $5,000 yearly	21,000	26,000	5,000*	26,000	5,000*	26,000	5,000*	26,000	5,000*
3. Annual conference—increase net income $15,000	5,000	20,000	15,000	20,000	15,000	20,000	15,000	20,000	15,000
4. Contractors—include as Associate Members; annual dues $50 (Schedules 1 & 2) or $75 average (Schedules 3 & 4); 1,000 such members assumed	—	50,000	50,000	50,000	50,000	75,000	75,000	75,000	75,000
5. Associate Members—increase dues on graduated scale to yield following average per member: $210 (Schedule 2), $385 (Schedule 3), $750 (Schedule 4); 315 such members assumed (same as at present)	31,000	31,000	0	66,000	35,000	121,000	90,000	236,000	205,000
6. Corporate Members (& MSS)—increase dues on graduated scale based on no. of services; 1,300 such members assumed (same as at present); bonus of 2 free $15 members for each Corporate Member at cost of $39,000: No. of Services — Sched. 2 — Sched. 3 — Sched. 4 1,000 or less — $35 min. — $35 min. — $34 min. Next 24,000 — 0.6¢/svc. — 2.0¢/svc. — 3.5¢/svc. Next 75,000 — 0.3¢/svc. — 1.3¢/svc. — 2.1¢/svc. Over 100,000 — $400 max. — $1,490 max. — $2,460 max.	32,000	32,000	0	147,000	115,000	415,000	383,000	702,000	670,000
Total (3rd year increase)	239,000	339,000	100,000	489,000	250,000	837,000	598,000	1,239,000	1,000,000
2nd year increase (80% dues)					199,000		507,000		804,000
1st year increase (60% dues)					149,000		416,000		609,000

* First year; estimated to increase $5,000 each succeeding year until increase totals $50,000.

unless such recommendations affected the collection of additional revenues in one way or another. Recommendations 1, 3, 4, and 5 are made because of the effect they will have, either immediately or in the future, in connection with the collection of additional revenues.

Recommendation 1 needs very little comment. In order to make a sale, it is absolutely necessary to have a product to sell. Without a definite program, completely and well thought out, there will be nothing to sell for the additional dues that are to be charged. Therefore, it is recommended that the Board of Directors coincidently determine the program that the Association is to undertake and approve the methods recommended for raising additional funds to support this program.

Recommendation 2

Through the fault of no one, the Subcommittee on Finances was handicapped in starting its study because of the fact that no specific dollar goal was given it to implement the proposed program of the Aims and Objectives Committee. Therefore, the subcommittee initially studied four plans involving the raising of funds in the amount of $100,000, $250,000, $500,000, and $1,000,000 above the $527,450 income shown in the 1960 AWWA budget.

Schedule 1

Schedule 1 outlines the plan for raising $100,000. Item 1 of this schedule provides for an increase of $30,000 by increasing advertising rates 20 per cent. Revenues in the 1960 budget amount to $150,000 for advertising. A 20 per cent increase would amount to $30,000. There is some question in the minds of the AWWA staff whether a 20 per cent rate increase would raise the revenue anticipated. Even if this is so, however, the subcommittee feels that measures can be taken to secure another $30,000 in advertising income.

Item 2 of Schedule 1 provides for an increase in the amount of $5,000 for publications the first year. The AWWA staff estimates that the net income from publications over a 10-year period could be increased $50,000 above the present figure, at the rate of $5,000 per year. This could be done through advertising, increased promotion, and a reexamination of the prices presently charged for publications.

Item 3 of Schedule 1 provides for an additional net income of $15,000 from the annual conference. In 1960, the committee is informed, the net income from the convention at Bal Harbour exceeded the budgeted net income of approximately $5,000 by $15,000, for a net total of $20,000. The additional income provided for in this item, therefore, has already been reached. It is safe to say that the net income could be increased another $5,000 or $10,000 by merely charging an additional $1 or $2 in the registration fee paid by each person attending the convention.

Item 4 of Schedule 1 provides for an additional $50,000 revenue by expanding the Associate Membership classification to include contractors at a proposed rate of $50 each. The various Sections of AWWA could very well be given the responsibility of promoting the sale of this type of membership in their territories.

The four items outlined will produce an additional income of $100,000 the first year this plan is in operation. As pointed out previously, Item 2 involving publications will increase at the rate of $5,000 each year so that at the

end of 10 years, with no other changes, the net income increase should amount to $150,000 per year.

Schedule 2

Schedule 2 outlines the method of raising $250,000 additional in operating revenues. Items 1, 2, 3, and 4, providing $100,000 additional revenue, are the same as in Schedule 1, and no further explanation is needed.

Item 5 of Schedule 2, which will produce an additional $35,000 per year, results from an adjustment of the Associate Membership dues applicable to manufacturers. Presently each such member is charged $100 whether he is a small manufacturer grossing $100,000 a year, or a large manufacturer grossing $50,000,000 a year. The Subcommittee on Finances recommends that staggered charges be made for Associate Memberships, the rates being sufficient to produce an average of $210 per member for the present 315 members in this classification. If $210 per member were realized, the resulting dues would be about $66,000. In view of the fact that the present dues for this group total $31,000, the net increase in income would amount to $35,000.

During the period in which this new membership plan is being put into force, if approved, it is recommended that the Associate Membership dues (and the Corporate Membership dues and Municipal Service Subscriber fees discussed below) be collected on the following basis: 60 per cent of the scheduled dues the first year; 80 per cent the second year; and from the third year on, the full dues as scheduled.

Under Schedule 2, the first year's gross dues for Associate Members would amount to $40,000, or an increase of only $9,000. The second year, dues would amount to $53,000, or an increase of $22,000; and in the third year, the full amount of $66,000 would be received, making the net increase $35,000.

Item 6 of Schedule 2 provides for an increase in Corporate Membership dues and Municipal Service Subscriber fees on a graduated scale based on the number of retail services. A minimum of $35 would be charged all members of this classification, the $35 minimum allowing two free individual members. This $35 minimum would be the fee charged for the first 1,000 services and would cover many of the smaller towns. A charge of 0.6 cent per service would be made for the next 24,000 services, and 0.3 cent for the next 75,000 services; for any city having 100,000 services or more, the charge would be a maximum of $400. Under this proposed plan, the dues from the cities represented by the 1,300 Corporate Members and Municipal Service Subscribers would amount to $186,000. From this amount should be deducted $39,000 representing the free memberships that would be provided under this plan, presumably to persons who are presently paying Active Membership dues. Also to be deducted is the total of $32,000 presently received from the Corporate Members and Municipal Service Subscribers. With the preceding deductions, the net increase in this type of membership dues would amount to $115,000. Again, out of a total of $186,000 increased dues the first year, 60 per cent, or $112,000, would be collected; the second year, 80 per cent, or $149,000; and the third year, 100 per cent, or $186,000.

As previously mentioned, these dues rates would be applicable only to the retail services of each utility, and where a utility sells water at wholesale to other utilities, cities, or districts, the appropriate dues would be collected

from the utilities purchasing the water. The same method of applying the rates would be used in Schedules 3 and 4.

Summarizing the increased revenue under Schedule 2, the total first-year increase would be $149,000, the second-year increase would be $199,000, and the third-year increase would be the full $250,000. As in Schedule 1, the net income from publications would increase $5,000 for the following 7 years.

Schedule 3

Schedule 3, the plan which seems the most desirable to the Subcommittee on Finances, provides for an increase of $598,000. Although it was originally intended that this schedule show an increase of $500,000, from a practical standpoint it appeared that whatever estimates were used, there would be some loss in revenue or some mistakes in estimating. Therefore, although the figures in this schedule indicate an increase in operating revenues of $598,000, it may be that the schedule will actually develop only half a million dollars of additional revenue.

Again, Items 1, 2, and 3 are identical to Schedules 1 and 2. In Item 4 of Schedule 3, which applies to contractors to be included in the Associate Membership classification, the dues have been averaged out at $75 per member rather than $50 as shown in the previous schedule. In Schedule 3 it is proposed that the membership fees should be staggered. Depending upon the amount of contracting done by any contractor in connection with the water utility business his fee would be $50, $75, or $100, and would be expected to average out at $75.

Item 5 of Schedule 3, applying to Associate Memberships covering manufacturers, is similar to Item 5 of Schedule 2, except that the staggered plan of dues under this classification would be expected to yield an average of $385 per member. As a result, there would be a $90,000 increase in revenue from manufacturers over their present dues.

The Membership Committee is proposing a staggered-dues basis for manufacturers, based on their gross revenue from the water industry. The dues suggested are $100 for all manufacturers having a gross revenue of less than $1,000,000; dues of $500 for manufacturers having a gross revenue of $1,000,000–$10,000,000; and $1,200 for manufacturers having a gross revenue in excess of $10,000,000. For lack of a more exact plan, and because it will be necessary to work out this plan with the manufacturers themselves, it is suggested that the plan of the Membership Committee be made a part of the recommendation of the Subcommittee on Finances, providing the plan as outlined will produce increased revenue of $90,000 per year.

Item 6 of Schedule 3, covering Corporate Members and Municipal Service Subscribers, also reflects increased dues or fees. The charge for the first 1,000 services would be a minimum of $35. The next 24,000 services would be paid for at a rate of 2 cents per service, and the next 75,000 at the rate of 1.3 cents per service. This membership classification will have maximum dues of $1,490, paid by cities with services totaling 100,000 or more. The increased revenue from this classification will amount to $383,000.

During the first year the plan is in force, at 60 per cent of the rates proposed in Items 5 and 6, the increase would amount to $416,000. The second-year increase, at 80 per cent, would be $507,000; and the third-year increase, at 100 per cent collection, would amount to $598,000. Again,

there would be a $5,000 increase in the net income from publications for the 7 years following the first 3 years this plan is in effect.

Schedule 4

Schedule 4 outlines a method of raising $1,000,000 additional in operating revenues. Items 1, 2, and 3 are the same as in the previous schedules, and no further explanation is required.

Item 4 of Schedule 4 is the same as Item 4 in Schedule 3.

Item 5 of Schedule 4, covering Associate Memberships for manufacturers, has been increased over the previous schedule so that an average of $750 per member would be realized from this classification.

Item 6 of Schedule 4, covering Corporate Members and Municipal Service Subscribers, has been increased on the following basis: A minimum of $45 would be charged utilities with 1,000 services and fewer. The next 24,000 services would be charged for at the rate of 3.5 cents per service, and the next 75,000 services would be 2.1 cents per service. Cities having 100,000 or more services would pay a maximum of $2,460. The increased revenue from this classification would amount to $670,000.

During the first year the plan is in force, at 60 per cent of the rates in Items 5 and 6, the increase would amount to $609,000. During the second year, at 80 per cent, the increase would be $804,000; and during the third year, at 100 per cent, the increase would amount to $1,000,000. Again, there would be a $5,000 increase in the net income from publications for the 7 years following the first 3 years this plan is in effect.

Although the Subcommittee on Finances did not know, and still does not know, what new programs will be approved by the Board of Directors, it appears that the additional revenue contemplated in Schedules 1 and 2, amounting to $100,000 and $250,000, respectively, would not be sufficient to finance the new programs recommended by the Aims and Objectives Committee. On the other hand, it appears to the subcommittee that the additional revenue of $1,000,000 included in Schedule 4 would, at the start of the program, be far in excess of the amount of money required to finance the new programs, and, more important, it would be extremely difficult to sell to the membership of AWWA because of the large amount of additional dues required from the various member classifications.

The Subcommittee on Finances originally contemplated that considerable money would be required for a research program by the Association. It appears, however, that once AWWA started a research program—at a cost, say, of approximately $100,000—grants would become available from various sources to continue the research; such grants are not presently available because no program of research is actually under way. If the Association were required to finance all of the research that is presently being considered, $1,000,000 additional revenue or more would undoubtedly be needed. Based on the understanding of the committee that research grants will be available once a nominal research program is started, it is felt that the additional income outlined in Schedule 3 is adequate.

In the Corporate and Associate Membership classifications (and Municipal Service Subscribers), where the most additional money will be developed, the committee believes that it would be far easier to sell, that less difficulty will be experienced, and that

more money will be secured if only 60 per cent of the dues is charged the first year, 80 per cent the second year, and 100 per cent the third year. This method of collection is, therefore, recommended.

Concluding the explanation of Recommendation 2, the figures included in all of the schedules are based on the present membership of the Association. It is felt that if the present membership can be completely retained and will completely support the dues as outlined, the amount of money estimated will be raised.

Recommendation 3

Recommendation 3 provides for the employment of an association consultant, using the advance contributions that will be paid in during the year 1961 before the new membership fees, if approved by the Board of Directors, are submitted to the general membership for approval. It is the thought of this committee that the association consultant would implement this recommendation by working out in detail the block rates and staggered rates recommended in Schedule 3. Also, the consultant should be requested to work with the AWWA staff to:

a. Recommend more specifically methods and procedures to be used in detail, redefining, describing, and outlining the membership grades and the dues to be charged for each kind.

b. Review the procedures being used by AWWA to outline areas of savings that might be realized in operations and other areas of income that may have been overlooked by this committee.

The consultant should also work with the proper group or committee to assist in implementing and setting up the new program to be approved. He could also be used in other areas, such as examining the different periodicals, including *Willing Water* and the JOURNAL, to see how they could better serve the entire membership, or making a study of office procedures.

It is the opinion of members of this committee who have used consulting engineers or management consultants that so often a utility is staffed in such a way that the management is constantly busy working on the day-to-day problems that arise, to the point that it has very little time left to study ways and means of improving the methods and procedures. As a result, even in the best regulated utilities, inefficiencies have a tendency to creep in. Without in any way, directly or indirectly, criticizing the AWWA staff, it is thought that a study of the methods, procedures, and operations of the Association might result in improvements and in the saving of money that is so badly needed. Therefore, this recommendation is made.

Recommendation 4

A number of members of the committee have found that other associations have men in the field promoting the particular association, selling it, answering questions about it, and getting new members for it. If the new dues schedule is adopted, there will be many utilities somewhat reluctant to pay the new dues until they know more about the program which they are to benefit from. It is suggested that one man, after careful study, be placed in a populous area to represent AWWA for the purpose of: (1) acquainting present members and nonmembers in the water works field with AWWA; (2) explaining the program of AWWA; and (3) securing renewal memberships and new memberships, as well as pushing the items that will result in additional revenue to AWWA. If this promotional effort

is successful, additional manpower may be placed in additional areas.

Recommendation 5

It is the experience of the committee that individual members are often required to pay their membership dues personally, as well as convention and traveling expenses if they are active in AWWA, notwithstanding the fact that all benefits that they receive accrue to the profit of the utility which they represent. It is the opinion of the committee that, in many areas, because of the lack of information about AWWA and the benefits that come about as a result of being a member of the organization, governing bodies such as city councils, boards of directors, or commissioners are reluctant or unwilling to pay the membership dues of water utility personnel working for them. It is the committee's recommendation, looking to the eventual securing of as much additional revenue as possible from new members, that a program of public information about the Association be commenced and information be disseminated throughout the country in an effort to break down the resistance to AWWA of many governing bodies and individuals.

Miscellaneous

The committee expects that, during the first several years on the increased-dues basis, there will be much controversy and a number of resignations among members. Within a few years, however, after the program recommended by the Aims and Objectives Committee is put into full force and effect and the benefits accrue to the members, it is the belief of the Subcommittee on Finances that resignations will be few and that any revenue lost during the first years will be more than made up in the years to follow.

The recommendations included in Schedule 3 for additional net revenue are the only specific recommendations this committee makes at this time. The committee does believe, however, that there are additional sources of revenue available to the Association which a management consultant can be helpful in developing, in cooperation with the AWWA staff and others.

As an example, many water utility people in the United States are not presently members of AWWA. A sales plan involving additional personnel can be worked out which will be self-supporting and profitable and materially increase the revenue of AWWA.

A further reexamination of the charges for handling periodicals and other services offered by AWWA might result in additional revenue.

Various water utilities have varying uses for the JOURNAL and the Annual Directory. Some savings in expense, and therefore increased net income, might be worked out in the case of utilities that do not require a Directory or JOURNAL for every employee who is a member of AWWA. On the other hand, it must be recognized that the saving might be largely offset by a corresponding loss in advertising revenue, since circulation and advertising rates are related.

Although the idea is undoubtedly controversial, an additional $34,000 would be picked up by requiring that the different Sections of AWWA become self-supporting. If this were done, the American Water Works Association would have $34,000 additional to spend for its program each year.

Relationship of Impoundment to Water Quality

S. Kenneth Love

A paper presented on Nov. 3, 1960, at the Chesapeake Section Meeting, Washington, D.C., by S. Kenneth Love, Chief, Water Quality Branch, USGS, Washington, D.C. Publication of this article has been authorized by the director, USGS.

As recently as 10 years ago "water quality" was a term used primarily by public and industrial water supply personnel, water chemists, and sanitary engineers; it was not commonly used or generally understood by the lay public. Today water quality is among the foremost topics discussed in both technical and nontechnical journals dealing with water supply development and use. The term also is common in the daily press, largely in connection with pollution. Water quality now occupies a position in the public mind more nearly consistent with its importance.

Among the many things that affect water quality is impoundment. Water quality may be improved or degraded by impoundment. Some of the more significant beneficial and detrimental effects of impoundment and the principal factors causing changes in water quality are discussed in what follows.

Beneficial Effects

Important beneficial effects of impoundment on water quality include: (1) reduction of turbidity, silica, color (in certain reservoirs), and coliform bacteria; (2) evening out of sharp variations in dissolved minerals, hardness, pH, and alkalinity; (3) reductions in temperature, which sometimes benefit fish life; (4) entrapment of sediment; and (5) storage of water for release in dry periods for the dilution of polluted waters.

Detrimental Effects

In addition to benefits, impoundment also has certain undesirable effects, including: (1) increased growth of algae, which may give rise to tastes and odors; (2) reduction in dissolved oxygen in the deeper parts of the reservoirs; (3) increase in carbon dioxide and frequently iron, manganese, and alkalinity, especially near the bottom; (4) increases in dissolved solids and hardness as a result of evaporation and dissolution of rock materials; and (5) reductions in temperature, which, although sometimes beneficial, may also be detrimental to fish life.

Causes of Quality Changes

What are the principal factors that give rise to beneficial and detrimental changes in water quality? Among the more significant factors are differences in density of both the inflowing and the stored water. These density differences are caused by variations in

temperature, salinity, and suspended matter. Reduction in velocity of inflowing turbid water can cause a reduction in density by permitting suspended matter to settle out. Other factors affecting water quality are evaporation, wind movements, dissolution or precipitation of mineral species, and biologic activity.

Density Flows

One of the most comprehensive studies of reservoirs was made on Lake Mead in 1948–49. The final interpretive report covering this study was published recently by USGS.[1] Of particular interest are the patterns of water circulation and salinity distribution. These patterns are controlled

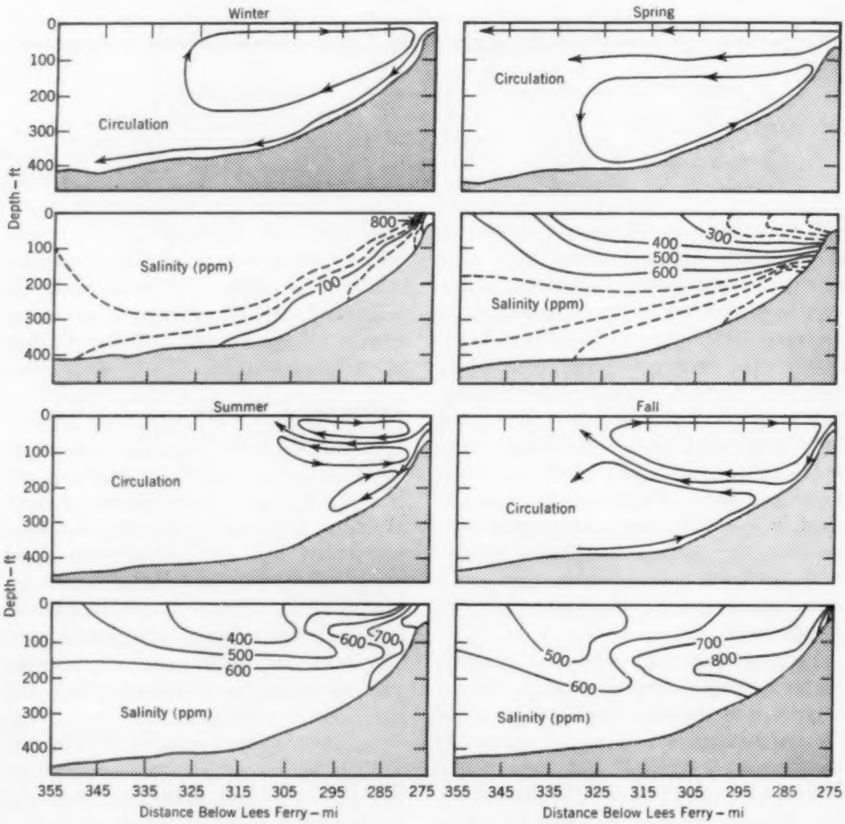

Fig. 1. Seasonal Salinity Distribution and Circulation Patterns, Lake Mead

Seasonal variations in temperature gradients are shown in Fig. 2.

largely by density flows, which vary markedly with seasons of the year. Three kinds of density flows are described—overflows, interflows, and underflows.

An overflow takes place when inflowing stream water spreads over the surface of the reservoir. The overflow may travel for a considerable distance and then mix with water near the surface by action of wind and waves.

An interflow takes place when the density of the inflowing water is greater than that of water on the surface of the reservoir but less than that of deep water. The inflowing water sinks to its own density level in the reservoir and then spreads out laterally downstream.

An underflow takes place when the density of the inflowing water is greater than that of the water at any level in the reservoir. The inflowing water sinks to the reservoir bottom and travels downstream at or near the bottom, usually along the old river channel.

Figure 1 shows seasonal salinity distribution and circulation patterns in Lake Mead. In winter there is almost complete vertical mixing of water throughout the lake, and there is a simple circulation pattern. The inflowing water is colder and more dense than the lake water and flows downstream as an underflow.

The greatest quantity of runoff occurs in the spring when the flow is low in dissolved solids and high in suspended solids. At this time the temperature of inflowing water is about the same as that of the surface of the lake and the sediment settles out rather quickly. Thus, the inflowing water proceeds into the lake as an overflow. Stratification of the lake waters takes place with a vertical gradient of temperature and salinity. The flow along the surface sets up a cellular circulation below 150 ft, which causes an upstream flow along the bottom.

In the summer the inflow decreases in volume and increases in salinity. The downstream travel of the river water takes place as an interflow at a depth of about 80 ft.

In the fall, the decrease in the temperature of the inflow causes greater sinking of the river water along the bottom as an underflow until it comes

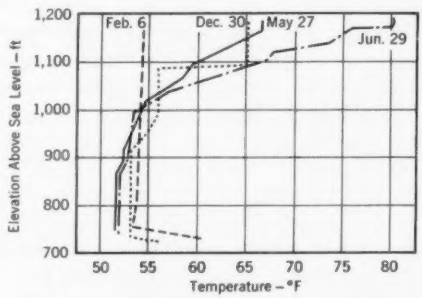

Fig. 2. Seasonal Variations in Temperature Gradients, Lake Mead, 1948

Temperatures were measured at the intake towers of Hoover Dam.

in contact with heavier water and then spreads out horizontally as an interflow.

Seasonal effects on temperature gradients in Lake Mead are illustrated in Fig. 2.

Figure 3 shows the weighted average salinity of inflowing and outflowing water in Lake Mead for the 15 years from 1935 to 1950. The large increase in salinity of outflow over inflow is contrary to observations made on most reservoirs. In this example the salinity increase in the early years after closure of the dam was caused princi-

pally by dissolution of large quantities of gypsum and common salt. After 1945 the difference was reduced gradually. In 1951, not shown, the difference was only 14 ppm and in the reverse order. Since 1951 the differences have been relatively small, salinity being sometimes higher in the inflow and sometimes higher in the outflow.

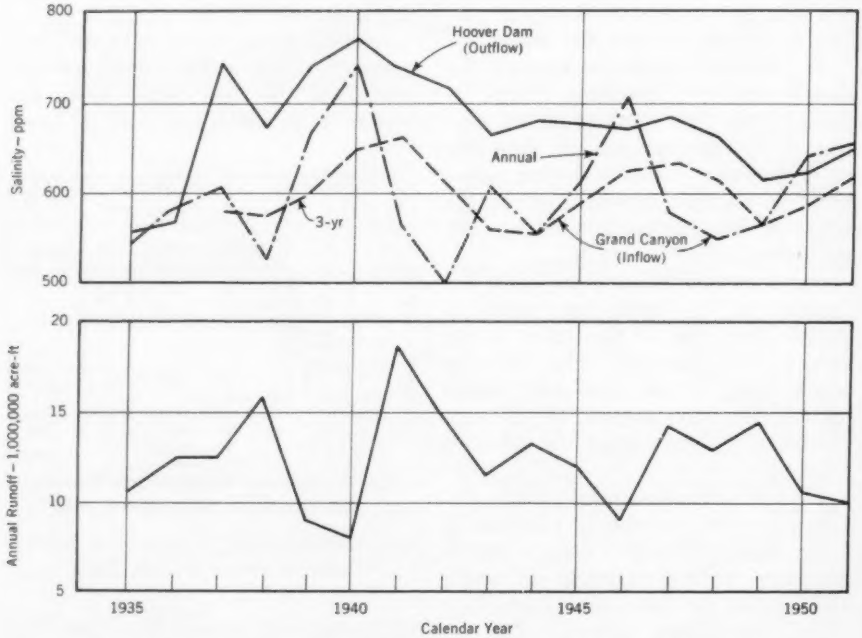

Fig. 3. Weighted Average Salinity and Runoff, Lake Mead, 1935–50

The large increase in salinity of outflow over inflow is an unusual phenomenon, caused principally by dissolution of large quantities of gypsum and salt. The difference has decreased in recent years.

Tennessee Valley Studies

Churchill [2] has summarized 20 years' experience in the Tennessee Valley, giving many interesting details about the effects of impoundment on water quality. He cites the usual benefits of decreased turbidity, color, bacterial concentration, BOD, and smoothing out variations in dissolved solids. He also lists the usual detrimental effects such as increase in algae and associated taste and odor problems, and the decrease in the content of dissolved oxygen.

Some of the effects cited by Churchill merit brief discussion. For example, there was a large increase in iron and manganese in the public water supply of Bristol, Tenn., which is taken

from the Holston River just below the reservoir. The normal outlet gates were closed for inspection and the bottom gates opened. This resulted in 6 ppm iron and 15 ppm manganese in the raw water. When the lower gates were opened the raw-water intake for Bristol withdrew this poor-quality water. Because chlorination facilities were not adequate to oxidize such large concentrations, rather large amounts got into the finished water, thereby causing considerable damage.

Another unusual situation developed at Harriman, Tenn.,[3] where the water plant intake from the Emory River is only a short distance above the sewage outfall. When the level of Watts Bar Reservoir rose, the intake and outfall were both covered and the velocity of the water was greatly reduced. In fact, at certain times the inflow was reversed so that sewage effluent moved upstream past the raw water intake.

Oxygen Depletion

The depletion of oxygen in the deep parts of lakes and reservoirs has received considerable attention in recent years. Churchill cites several examples in the Tennessee Valley. Kittrell[4] has reviewed the broad spectrum of the effects of impoundments on dissolved-oxygen resources.

Dissolved oxygen in surface waters is coming to be regarded, quite properly, as an important resource. Oxygen is the principal factor in the natural self-purification of organically polluted streams. If the dissolved oxygen is reduced unnaturally, as happens in the deep parts of reservoirs, the reduction itself can be considered a form of pollution. Some workers have expressed oxygen depletion in terms of "population equivalents." For example, oxygen depletion below Catawba Reservoir in South Carolina was computed by Ingols[5] to be equivalent to pollution from a city of 1,000,000 people. In at least one state, damage to downstream users as a result of oxygen depletion in impounded water has been defined by law as pollution damage.

In the Kerr Reservoir on the Roanoke River in Virginia, the water is highly stratified in the summer months. Dissolved oxygen is greatly depleted at the lower levels, from which water is discharged. In the 33 mi of open river between the dam and the backwater of Roanoke Rapids Reservoir, the pickup of dissolved oxygen remains well below the saturation point. Thus water enters the lower reservoir partially depleted of oxygen. Water released from the lower levels of this reservoir, in turn, is greatly deficient in oxygen. The low oxygen content and the low temperature are highly detrimental to certain species of fish that spawn nearby.

Reaeration and Dissolved Oxygen

Reaeration of water released from reservoirs is receiving increasing study. Natural reaeration is the principal mechanism for oxygen dissolution at present. As would be expected, reaeration is more effective in turbulent water than in quiescent water. A good example is the stretch of river below Boone Reservoir on the South Fork of Holston River. The high reaeration capacity of the river was suddenly reduced by the construction of a second reservoir downstream which flooded the turbulent section of the river.

Artificial methods of reaeration have been tried. Compressed air has been used with some success to mix warm

surface water with cold deep water in a small reservoir.[6]

In Lac de Bret in Switzerland, cold water is pumped from the lower levels through an aeration chamber and returned to the same depth at some distance from the pump intake.

In the construction of Whiskeytown Dam near Redding, Calif., provisions are being made to mix warm surface waters with cold deep water to a temperature that will accommodate fish.[7] This will also provide a higher dissolved-oxygen content than releases from the deeper levels only.

It has been suggested that multilevel penstocks should be provided in reservoirs so that releases would be made from several levels, thus furnishing water of better quality for downstream users.

Dilution by Impounded Water

One of the benefits of impounded water is that it provides dilution for various kinds of wastes. Dilution may take place in the reservoir itself or in the stream below the dam. Releases of impounded water which exceed normal runoff provide the necessary extra water. Dilution should not be used as a substitute for treatment, however.

Churchill reports an example in which both oxygenation and dilution provided some, but not adequate, antipollution effects. The inflow to Boone Reservoir carries a large load of ammonia from an upstream industrial plant. When the waste enters the lower level of the pool in a density interflow, some oxidation takes place, but when the available oxygen is used up the unoxidized ammonia remains unchanged and is eventually discharged from the reservoir.

Algal Growths

An usual effect of storage took place in a farm pond in central Texas. Davidson[8] reported a waterbloom of *Nostoc rivulare* Kuetz, an alga that is poisonous to wild and domestic animals. Cattle, fish, frogs, and fowl that drank the water became acutely ill, and many died. Although a bloom of this particular alga may never occur in a large reservoir, it might take place in other ponds or small reservoirs with equally unfortunate results.

Heat Dissipation

Impounded water can be used for the dissipation of heat. A report by Harbeck[9] indicates that, for the dissipation

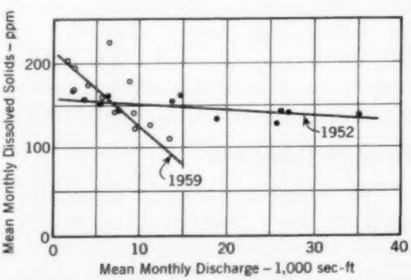

Fig. 4. Relationship of Monthly Mean Dissolved Solids to Streamflow, Potomac River

Shown are monthly mean measurements for 1952 and 1959.

of excess heat resulting from certain industrial processes, substantial savings in water often can be realized by impoundment, as compared with cooling-tower methods—provided, of course, that it is practicable to withdraw water from a reservoir, let it absorb heat, return it to the reservoir, and leave it there long enough before reuse. For two reservoirs studied, annual savings

in water were 45–50 per cent. Of course, the addition of heat to a reservoir reduces the dissolved-oxygen content; it also increases evaporation and biologic activity, unless the quantity of warm water added is small in comparison with the volume of water in the reservoir.

Velz [10] has developed quantitative relationships for forecasting heat loss in surface water. The four principal mechanisms involved in heat transfer from reservoirs are evaporation, convection, radiation loss, and solar radiation gains. Thus, by using a rational method for forecasting expected water temperature conditions, it is possible to predict temperature effects in a reservoir before its construction and evaluate the effects of the reservoir and its operation on stream sanitation.

Impoundments and Radioactivity

A great deal of attention is being given to potential hazards arising from pollution of surface waters by radioactive materials. Results of several studies show that surface waters are especially susceptible to radioactive pollution and once polluted cannot be used as safe sources of supply until the hazardous material is flushed out, decays, or both. Even then, the adsorption of activity on sediments and biota poses difficult problems.

Intelligent operation of reservoirs based on a knowledge of seasonal stratification, flow patterns, density currents, and other characteristics, in addition to a knowledge of the kind and intensity of radioactivity present, may make it possible to provide safe water for a considerable period of time. This is especially significant for persons charged with the responsibility of finding emergency water supplies.

For example, if a spill of dangerously radioactive material reaches a stream above a reservoir during the warm, summer months, most, if not all, of the pollutant will enter the reservoir as an overflow and will be confined to the surface layers. If reservoir releases are confined to the deeper water, then, through natural decay, the radioactive material in the surface layers, especially if composed of shorter-lived nuclides, may reach a relatively harmless low-activity level before it has a chance to mix with the deeper water. This would be true only if little or no suspended matter were present in the inflowing water, however; otherwise radioactive sediment could settle to the bottom of the reservoir and interfere with the release of uncontaminated deep water.

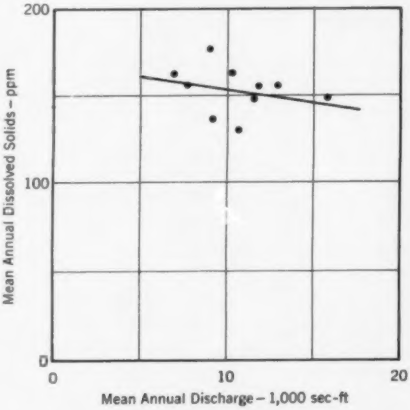

Fig. 5. Relationship of Annual Mean Dissolved Solids to Streamflow, Potomac River

The data plots are for the calendar years 1942–43 and 1952–59.

If, on the other hand, a spill occurs in winter, when most or all of the

inflow takes place as an underflow, reservoir releases should be made from near the surface of the reservoir. Owing to the tendency for nearly complete mixing of water during the winter, the period of safety from mixing is much shorter than when the water is stratified.

Thus the factor of safety that could be provided with regard to radioactive pollution is another justification for multiple outlets from different vertical levels.

Potomac River Quality

Records of chemical quality of the Potomac River have been collected for many years at the Dalecarlia filtration plant. The dissolved-solids content, based on monthly composites of daily samples, ranges 95–225 ppm.[11] As would be expected, there is a general inverse relation between streamflow and dissolved solids. Figure 4 compares the high water year, 1952, during which the monthly dissolved solids varied through a relatively narrow range, with the dry year, 1959, when the variations were much greater. Figure 5 shows the relation between discharge and dissolved-solids concentrations, based on annual mean measurements.

Any significant impoundment near Washington, D.C., such as has been proposed for River Bend, would tend to smooth out variations in dissolved solids. The dissolved-oxygen content would be lower in the released water. If, on the other hand, the dam is located above Great Falls, the passage of released water over the falls will restore, by aeration, much of the dissolved oxygen lost during impoundments.

Sediment in Potomac Basin

In 1951, USPHS estimated[12] that erosion contributes an average annual mud load of 1,700,000 tons to the Potomac River at Washington.

TABLE 1

*Particle Size Analysis of Suspended Sediment, Potomac River**

Date	Size Distribution—*per cent*			Storm
	Clay	Silt	Sand	
Oct. 1959	77	20	3	Hurricane Gracie
Jan. 1960	60	38	2	winter rainstorm
Apr. 1960	25	70	5	snowmelt runoff
Apr. 1960	32	62	6	rain after snowmelt

* At Point of Rocks, Md.

Abel Wolman,[13] in 1957, using data supplied by the US Army Corps of Engineers, estimated an annual sediment production of 60,000,000 cu ft at Washington, most of which is deposited in the metropolitan area. The factor for converting tons of sediment to volume was not given, but if it is assumed that 1 cu ft is 60 lb, the 60,000,000 cu ft would be equivalent to 1,800,000 tons.

Computations from the results of reconnaissance studies made by USGS during 1960 indicate that the annual sediment load at Point of Rocks is

about 2,000,000 tons. Assuming the same rate of sediment transport downstream from Point of Rocks, but excluding Rock Creek and the Anacostia River, the annual load at Washington would be 2,300,000 tons. If these two tributary streams are included, then the annual load is estimated to be 3,000,000 tons.

The trap efficiency of a reservoir at River Bend has been discussed rather widely. The popular view, also held by some technical groups, is that a reservoir immediately above Washington will trap almost all of the sediment flowing into it. In the author's opinion, this is extremely doubtful.

There is no doubt that almost all of the sand moving into the reservoir would be trapped, but particle size analysis of suspended sediment collected at Point of Rocks indicates that less than 10 per cent of the suspended sediment consists of sand.

Table 1 shows the size distribution of four samples of suspended sediment collected between October 1959 and April 1960. All of the samples were collected during periods of storm runoff, because a large percentage of the annual load is transported during such periods. It is significant that nearly all of the material was in the silt and clay size fractions and that there was wide variation in distribution within these size fractions.

How much sediment is trapped in a reservoir and how much passes through depend in large measure on the nature of the sediments and the manner in which the reservoir is operated. In view of the multiple interests served by a large reservoir, it is reasonably certain that it could not be operated in the manner most conducive to the entrapment of sediment. Most of the sediment would be trapped, but some fine material would pass through. In view of the already large, but still rapidly expanding, amounts of sediment from urbanization, periodic dredging of navigation channels below Key Bridge still would be necessary, although probably more infrequently.

Conclusion

Many studies of stream impoundments have been made, and much valuable information has been obtained. Unfortunately, most of the studies have been more qualitative than quantitative. Even when water characteristics have been reported quantitatively, overall evaluations of water storage projects and their relation to multipurpose interests have been largely qualitative.

There is increasing need for more thorough studies of stream impoundments in terms of parameters usually passed over lightly or completely ignored. If adequate information were available from existing impoundments, it should be possible to evaluate all pertinent factors and thus predict, in designing a new dam, what effects the dam and reservoir will have on both natural resources and cultural developments in the area. When the art of dam construction and reservoir operation reaches this high level of proficiency, it may be that most of the controversial technical problems attending proposed stream impoundments can be resolved in advance.

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Watershed Management and Reservoir Life

Otis L. Copeland

A paper presented on Oct. 6, 1960, at the Intermountain Section Meeting, Salt Lake City, Utah, by Otis L. Copeland, Chief, Div. of Watershed Management Research, Intermountain Forest & Range Experiment Station, US Forest Service, Ogden, Utah.

RECENTLY, an article in a major publication of USGS stated [1]:

> Reservoirs are becoming an increasingly prominent feature of the American landscape. Built for flood mitigation and to change a fluctuating river into a dependable source of water for irrigation, power, and other purposes, they are predestined, like natural lakes, to be destroyed some time following their creation.

This is a disturbing and distressing commentary; it causes one to wonder why, if it is indeed true, it need be true—why present knowledge of watershed management principles is not being better applied.

Unfortunately, the statement is borne out by the facts. Siltation of ponds and reservoirs in widely separated localities is slowly filling up the nation's reservoirs. Seventeen reservoirs constructed for flood control and erosion abatement in a 23-sq mi drainage area (Cornfield Wash) in northwestern New Mexico lost 39 per cent of their capacity in the first 5 years of operation, 1951–55.[2] Sediment deposited in Lake Mead in 14 years (1935–48) totaled two billion tons.[1] The Imperial Dam on the lower Colorado River in California had, at the time of its closure in 1938, a capacity of 85,000 acre-ft. After 22 years, its capacity is only 1,000 acre-ft.[3]

The Guernsey Reservoir of the North Platte project in Wyoming and Nebraska has lost one-third of its original capacity.[4] From 1915 to 1945, the Elephant Butte Reservoir lost 17 per cent of its storage capacity.[1] Sediment from eroded watershed lands has destroyed about 16,000 acre-ft of storage capacity in the Sevier Bridge Reservoir in central Utah.

Numerous other examples can be cited to attest to the validity of the statement quoted above. Reservoirs are being destroyed by accelerated erosion—and at a much faster rate than that of normal geologic erosion.

Before one can establish whether this condition must exist—whether the many reservoirs now being constructed are predestined to be destroyed—one must examine the multiple facets of watershed management and gain a better understanding of what is involved.

Watershed management is the scientific application of the principles of watershed processes for the protection, improvement, and management of watersheds, and has these basic objectives: (1) to improve water supplies; (2) to reduce the range between extremes of streamflow (especially low flows and destructive flooding); (3) to reduce sediment production; and (4) to improve water quality for diverse uses.

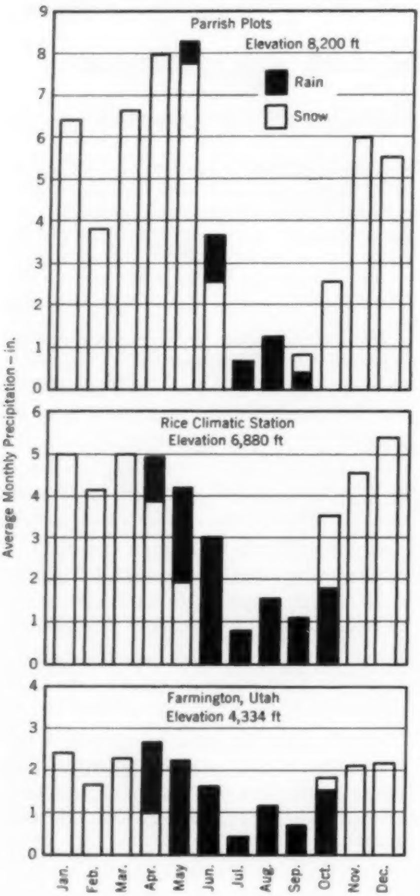

Fig. 1. Average Monthly Precipitation at Three Elevations

Shown is the average monthly precipitation for three elevations on the Davis County Experimental Watershed, near Farmington, Utah. Annual precipitation for the three locations is: Parrish Plots, 53 in. (93 per cent snow); Rice Climatic Station, 43 in. (74 per cent snow); Farmington, 21 in. (56 per cent snow).

Davis County Watershed

To provide a better understanding of the principles and problems of watershed management, one area will be examined in detail here. The data were obtained largely from the Davis County Experimental Watershed, situated in the Wasatch Mountains midway between Salt Lake City and Ogden, Utah.[5]

In this Intermountain area, precipitation normally occurs in each month of the year (Fig. 1).[5] During winter and spring months it comes from gentle, widespread, cyclonic storms; in summer months it is derived from local thunderstorms of short duration and high intensity. Records obtained for 250 storms over the headwaters of the Parrish Creek watershed (elevation 8,260 ft) between 1936 and 1958 show that rainfall depth for 72 per cent of these storms was less than 0.25 in. with 5-min. intensities of less than 1 in. per hour. Intensities of the other storms ranged from 1 to more than 6 in. per hour. These high-intensity storms pose problems relating to both soil erosion and water supply.

Land Use and Water Yield

In the state of Utah, a land area of about 52,700,000 acres, the principal water-yielding lands comprise less than 20 per cent of the total area. They are situated at elevations of 6,000 ft or more, and most of them are under national forest management. The kind of management applied to these high-elevation lands determines the amount and quality of the water they yield. The management of water-yielding lands is a problem in the management of steep slopes.

To show the effects of land use on water yields, it is useful to compare

the discharge characteristics of two adjacent mountain watersheds of contrasting use history. Plant cover on the Centerville Creek watershed has not been depleted, and the watershed has not flooded since settlement in the area 113 years ago. The adjacent Parrish Creek watershed produced four devastating mud-rock floods in 1930 after destruction of vegetation by burning and overgrazing on the headwater lands (Fig. 2). To reestablish flood control and stabilize the soils, vegetation was restored on the depleted and eroded areas by contour trenching and reseeding (Fig. 3).

Normal annual discharges from both watersheds are characterized by a rapid rise shortly after the beginning of snowmelt late in March, a brief period of maximum discharge in May, a rapid recession of flow in June, and a more gradual recession of flow through the remaining months.[5]

Streamflow recedes rather quickly after the spring peak, and during most seasons this recession is interrupted only temporarily by brief summer rainstorms that cover small areas. On damaged watersheds, these short-duration storms may cause a sudden sharp peak in the flow several hundred times greater than the normal maximum that results from snowmelt. This is illustrated by a 1947 flood from Halfway Creek which was caused by a storm producing a depth of only 0.79 in. of rain but whose intensity was 4.92 in. per hour (Fig. 4).[6]

At this point, attention should be called to the effect of the rehabilitation on Parrish Creek watershed. Because the watershed now functions properly, the storm of Aug. 19, 1945, whose in-

Fig. 2. Result of Depletion of Plant Cover

The area shown was formerly a good grazing area in the head of Parrish Creek. As a result of lost plant cover, even these low-gradient slopes contributed heavily to the floods.

tensity was 6.8 in. per hour, produced a peak flow of only 5 cfs/sq mi (csm).*

Records and observations on streams in the area show that 95–99 per cent of the annual streamflow is yielded as seepage flow. The remainder is derived from channel interception and overland flow. Seepage flow is desirable and extremely valuable because it is yielded regularly in a clear, filtered condition.

Moreover, if all plant cover were removed from a watershed, floods and sedimentation would soon reach such volumes as to render the water of little or no value. Portions of the Parrish Creek watershed were essentially bare of cover in 1930, and that situation gave rise to unprecedented mud-rock floods. The four floods in 1930 deposited 330 acre-ft of sediment on valley lands at the mouth of the stream (Fig. 5). The 2.15-sq mi watershed and damaged channels produced sediment at the rate of 153 acre-ft/sq mi. Of course, this represents a short-time condition of a highly unusual nature, but a reservoir serving similar areas would soon find its useful life expended.

Fig. 3. Contour Trenches After High-Intensity Rain

These trenches were designed to hold 1.5 in. of runoff. The trenching was part of a reseeding program on Parrish Creek watershed.

Effect of Plant Cover Removal

Removal of all plant cover from a watershed would probably result in the greatest obtainable yield of water. Even if adequate reservoirs were available for storing the increased runoff, however, losses from evaporation would reduce the supply materially.

Plant Cover Restoration and Yields

Annual flow. When plant cover is restored to partially or completely de-

* A flow of 1 csm is equivalent to 0.03719 in. in depth of runoff from 1 sq mi over a period of 24 hr.

nuded areas, it is only natural to anticipate greater transpiration losses.

For example, after cover restoration on the damaged Parrish Creek watershed, diminution of water yield from the rehabilitated drainage area totaled 2.7 in., which represents a decrease of 23 per cent in annual flow over a 22-year period.[5]

a marked decline in streamflow during the first 11 years, amounting to 2.24 in., or 83 per cent of the total change; however, during the last 11 years, the minor decrease in annual flow is insignificant.

One might hastily attribute the decrease in annual water yields to an increase in density of riparian vegeta-

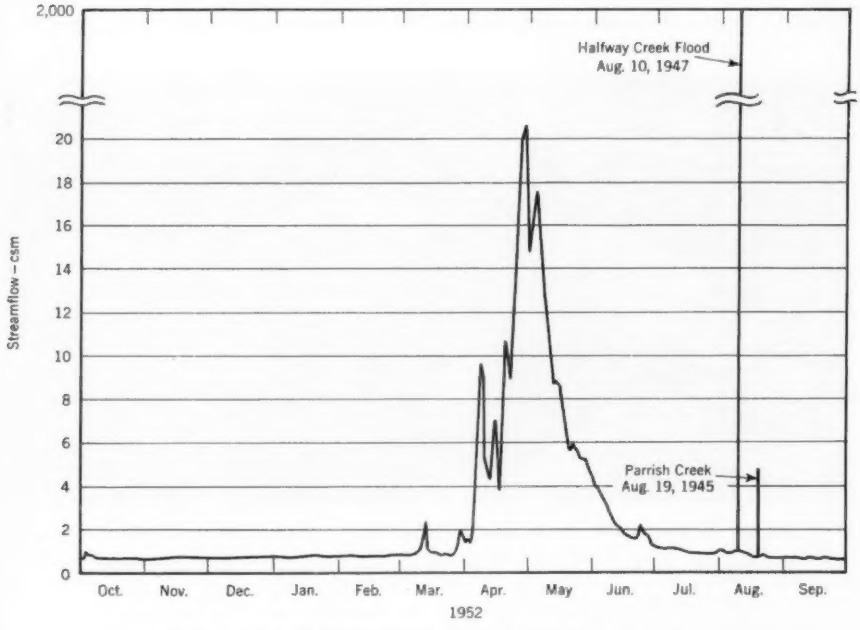

Fig. 4. Daily Hydrograph of Halfway Creek, 1952

The summer flood peak of Halfway Creek on Aug. 10, 1947, and the maximum peak generated by a larger storm on Parrish Creek watershed on Aug. 19, 1945, are superimposed on the hydrograph.

Deviations of the actual flows from expected flow were plotted (Fig. 6). Their values, represented by the solid sloping line, suggest a definite downward trend for the first 11 years. Thereafter, no discernible trend is apparent. Two additional analyses show

tion, but a circumspect examination of monthly time-trend analyses refutes this assumption. More than three-fourths of the decrease occurs during the early spring months before transpiration losses become significantly large.

Changes in peak time. Streamflow from Parrish Creek has been altered in another way. During the few years following rehabilitation, Parrish Creek tended to peak in the spring approximately 3 days earlier than the more stable Centerville Creek. Over the 22-year period, a gradual change in the relative timing of peaks has developed. Parrish Creek now tends to peak 3 days later than Centerville Creek. This trend has an explanation —a greater amount of snowmelt is now required to satisfy the moisture storage deficit before enough runoff can accumulate to form a spring peak.

Summer low flow. Summer streamflow in July, August, and September (shown in Table 1), while of vital importance in the Intermountain Region, comprises only 13.3 and 9.3 per cent of the annual runoff from the Centerville and Parrish watersheds, respectively. The summer low flow of Parrish Creek since 1937 averages only 1.10 in. The total decrease in summer low flow attributed to watershed rehabilitation is 0.35 in., or an average of 0.016 in. per year.

Seasonal low flow. Streamflow for the 9 months of June through February is designated "seasonal low flow." It amounts to 48.4 per cent of the annual discharge for the Centerville Creek watershed and 38.3 per cent for the Parrish Creek watershed (Table 1). Over the 22-year study period, seasonal low flow decreased slightly, but not enough to be statistically significant. The total reduction amounts to 0.55 in. or 0.025 in. per year.

Decreases in streamflow volume are important not only in the light of their effect on water for irrigation and domestic supply. Of equal or transcending importance is the improved regularity and quality of low flows in enhancing electric power generation, recreational developments, and fish and wildlife habitats. These facets of water

Fig. 5. Boulders and Flood Debris Deposited by Parrish Creek Floods, 1930

The largest boulder deposited by the flood was computed to weigh 200 tons.

utilization can be influenced favorably by rehabilitation of damaged watersheds—and at very modest cost in water yield.

Streamflow for the month of June deserves brief mention. From a water yield standpoint, it is especially interesting that the time-trend analysis for June shows a definite tendency for streamflow to increase. An actual increase of 0.224 in. occurred during the study period. Although this amount is not statistically significant, the direction of the change is considered highly encouraging and is attributed to the postponement of the occurrence of peaks until later into the season. It is not unreasonably presumptive to equate the small increase in June streamflow to the decrease recorded for May.

Sedimentation

Sediment production depends upon several factors, particularly the nature and depth of soil material, steepness of slope, nature and amount of precipitation, and the protection afforded by vegetation.[7] Geological evidence shows that normal erosion is low even on steep but well vegetated watersheds of the Intermountain area. When the delicate balance between climate, soil, and vegetation is upset, this normally low rate can accelerate greatly.

Measurements of accumulated sediment from the small, 167-acre Morris Creek watershed indicate a normal sedimentation rate of about 0.0025 acre-ft/sq mi per year from this thickly vegetated watershed. Contrasted to this very low rate, an average annual sedimentation rate of 2.54 acre-ft/sq mi per year was determined for Farmington Canyon for the period 1923–47. While this canyon was in a flood source condition, its sedimentation rate was approximately 1,000 times greater than that from the well vegetated Morris Creek watershed.[6]

An illustration of potential sediment production as a product of erosion from steep mountainous terrain is shown in Fig. 7. The horizontal axis shows how soil development from bare rock proceeds under the protective soil-forming influences of plant cover and culminates eventually in a mature, deep soil mantle. The vertical axis shows that erosion from bedrock is low and keeps pace with the disintegration of the rock when plant cover is lacking. As soil develops, the erosion potential increases markedly, as shown by the broken line, but so long as the soil is

TABLE 1

Average Streamflow of Parrish and Centerville Watersheds Apportioned to Low- and High-Flow Periods

Period	Months	Parrish		Centerville	
		Avg Streamflow *in.*	Percentage of Annual Streamflow	Avg Streamflow *in.*	Percentage of Annual Streamflow
Jul.-Sep.	3	1.103	9.36	1.657	13.29
Jun.-Feb.	9	4.523	38.36	6.043	48.46
Mar.-May	3	7.267	61.64	6.427	51.54
Jan.-Dec.	12	11.790	100.00	12.470	100.00

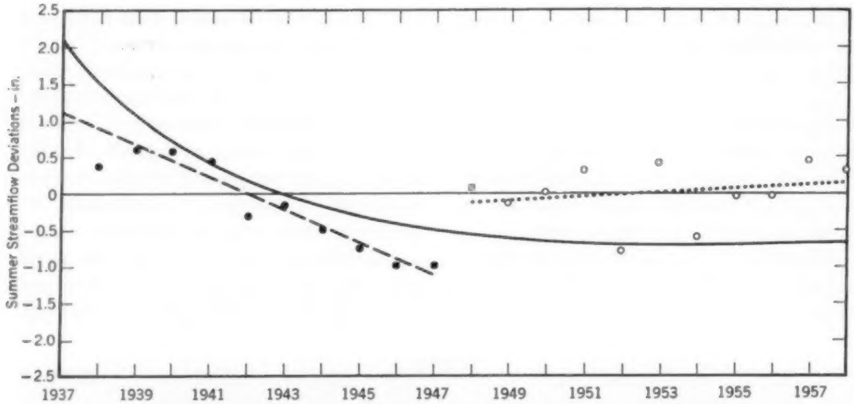

Fig. 6. Time-Trend Curves for Annual Streamflow, Parrish Creek

The solid curve represents the overall 22-year period; the dashed and dotted curves represent the first and second 11-year periods, respectively.

protected by plant cover, actual erosion remains low. Figure 7 reflects the sedimentation condition of Farmington Canyon a few years ago at the time of its high sediment production and that of the highly stable Morris Creek watershed whose sedimentation rate is negligible.

Yield Improvement

Studies have established certain principles of watershed management to increase water yields.[8] Among these are:

1. Deep-rooted plants create greater soil moisture deficits than plants with shallower root systems.

2. Deficits in soil moisture must be replenished before water will percolate through the soil to recharge ground water and maintain streamflow.

3. Thinning of dense coniferous stands on northern slopes in areas of heavy snowfall allows more snow to reach the ground and thereby increases water available to streamflow.

4. On deep soils, conversion from deep-rooted to shallow-rooted vegetation makes more water available for streamflow if conditions for infiltration are satisfactory and if precipitation is sufficient to wet down through the root zone.

Unfortunately, a treatment desirable for improving one feature of water yields may be incompatible with another that is equally desirable. Thus

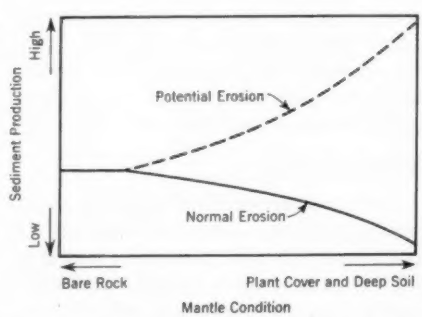

Fig. 7. Normal and Potential Erosion in Relation to Soil Development

As soil develops, the erosion potential increases markedly, but if the soil is protected by adequate plant cover, actual erosion remains low.

each situation must be resolved independently, and in light of the particular advantages and disadvantages that may develop.

Croft [9] estimated that for the period August to October 1944, evapotranspiration losses from streamflow in Farmington Creek were about one-third of the total streamflow. This study suggests that where the demand for domestic water supply is great it may be economically feasible to eliminate some loss by piping water through the lower main channel or by keeping vegetation to a minimum along the stream courses.

From 1947 through 1949 a study [10] of the disposition of precipitation on three aspen forest sites showed that the removal of aspen trees reduced consumptive water losses about 4 in. per year without causing any soil loss. Removing all plant cover and litter reduced consumptive water losses by an additional 4 in., but this denudation resulted in catastrophic soil losses averaging 185 cu ft per acre annually. One high-intensity storm of only 0.70 in. total precipitation removed 374 cu ft of soil per acre. Careful observations are being made to determine whether the herbaceous vegetation alone will continue to maintain soil stability under the impact of major storms.[6]

Erosion and Reservoir Life

To answer the question raised earlier—whether reservoirs are necessarily predestined to be destroyed—it must be remembered that erosion, which produces sediment, may either follow a normal geologic pattern or be unnaturally accelerated. Where there is a balance between climatic forces, vegetation, and soil, normal geologic erosion is a slow process and channel and reservoir sedimentation occurs at a minimum rate. On the other hand, when the normal geo-ecological balance is disrupted by man's activities, major impairment of normal watershed processes follows: infiltration is diminished, overland flow commences, erosion develops, and sedimentation increases. As increasing amounts of sediment are unleashed, the useful life of reservoirs is correspondingly reduced.

Thus reservoirs are predestined to be filled, but good watershed management can prolong the life of reservoirs by controlling erosion.

Needed Actions

To insure continued regulated supplies of high-quality water, certain actions will be needed in the future:

1. Area-wide watershed protection practices that have been proved by research and experience should be applied.
2. Research on unsolved watershed problems should be increased.
3. Both action and research programs pointed toward management, rehabilitation, and administration of the nation's soil and water resources on wildlands should be implemented.
4. Direct educational programs should be undertaken to insure a widespread and adequate understanding of the principles of, and necessity for, efficient management of natural resources, especially water.

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Manganese Deposits in Western Reservoirs and Distribution Systems

Henry C. Myers

A paper presented on Oct. 26, 1960, at the California Section Meeting, Long Beach, Calif., by Henry C. Myers, San. Engr., California Water & Telephone Co., Chula Vista, Calif.

PROBLEMS with manganese in water supplies are much more common than is generally recognized. The fact that occasional chemical analyses of a source of supply have failed to show the presence of manganese is not a guarantee that manganese problems are nonexistent. Occasional false chlorine residuals throughout a distribution system are likely to be one of the least expected results of the presence of manganese in the system. Common consumer complaints resulting from the presence of manganese concern red to black stains on laundered clothing and plumbing fixtures. Turbid water that may range in color from a chocolate brown to black, depending on the ratio of manganese to iron, results in numerous complaints and incessant flushing of lines. There may be a decrease in pipeline flow and incorrect meter readings due to thick incrustations. If water is from wells, there may be a clogging of the perforations, thereby reducing well production. Changes of flow in a distribution system loosen previously deposited material, resulting in muddy water. This can be a serious problem, even when the deposits are only $\frac{1}{32}$ in. thick.

Properties of Manganese

Manganese is next to titanium in abundance, constituting nearly 0.1 per cent of the earth's crust. Yet titanium is of no concern to the water supply industry, while manganese, because of its chemical behavior, is very much of a problem. Manganese is essential to both plant and animal life. It acts as an enzyme activator and is present in all plants. The manganese content of plants varies according to that found in the soil. The growth of diatoms is promoted by the presence of manganese. Certain bacteria, by either altering environmental conditions or by utilizing a portion of the manganese radical, deposit large quantities of manganese, even though only a minute quantity exists in the source of supply.

Manganese is precipitated as manganese carbonate when carbon dioxide is removed from bicarbonate by bacterial action. Certain bacteria utilize organic substances, which act as protective colloids. When this occurs, manganese is precipitated as the hydroxide. Reducing conditions such as as those that exist near the bottom of deep reservoirs tend to put the precipitated manganese back into solution. This cycle of precipitation in the epilimnion of the reservoir and its return to solution in the hypolimnion, with perhaps only a trace of manganese being continually supplied, produces a high manganese concentration in the deep water. The thermal stratification

of a reservoir, which promotes the buildup of manganese in the deeper water, is also the control that prevents manganese from being uniformly distributed throughout the water.

There appear to be very few deep-reservoir waters that do not show an increase in manganese concentration near the bottom. Whether or not this condition results in problems is determined by the depth at which water is withdrawn and by the nature of circulation within the reservoir. Problems may occur as a result of sudden and unexpected high concentrations of manganese due to the overturn of the reservoir water. A reservoir may show a low but continual manganese concentration of less than 0.1 ppm. Even this condition can lead to slime deposits in pipelines.

Salt Lake City

The pipeline of the Salt Lake City Metropolitan Water District in Utah, extending from Deer Creek Reservoir in Provo Canyon to the Terminal Reservoir in Salt Lake City, is about 40 mi long. It became coated with a black deposit of iron and manganese in about 1955. When the black coating is only about $\frac{1}{32}$ in. thick, it breaks off and colors much of the water. The length of the line makes it difficult to maintain a free chlorine residual. Furthermore, although the manganese concentration ranges from only a few hundredths of a part per million to 0.1 ppm, it is continual for much of the year. The Deer Creek Reservoir outlet is at the bottom of the dam, and the concentration of dissolved oxygen becomes less each year after the spring turnover, until it reaches zero. The manganese concentration increases during times of low oxygen concentration. The district has cleaned the pipeline each year since 1955. Because it was thought that chlorination may have added to the problem, the chlorine dosage was reduced. This made matters worse, however, because there was less control of pipeline slime growths.

San Diego County

Well waters in most of the valleys in California's San Diego County contain manganese. The streamflows never contain manganese, but nearly all wells in the Otay, Sweetwater, Mission, San Luis Rey, and Tia Juana valleys contain high concentrations of the element. Many of these waters are also quite highly mineralized, and the water is used only for agricultural purposes. Wells in the San Luis Rey Valley contain as much as 16 ppm manganese. The presence of the element in so many of these ground waters is not surprising, for such manganese-containing minerals as rhodonite, rhodochrosite, and pyrolusite are found in the mountainous regions of the county. It is probable that much of the manganese in the reservoirs is the result of leaching from sedimentary manganese materials.

San Clemente

Although many wells in the Carmel Valley in Monterey County, Calif., contain considerable concentrations of iron, they have not been found to contain manganese. The element is present, however, in the bottom water of San Clemente Reservoir, which is on the Carmel River. As manganese is not found in the ground waters, its presence in the reservoir is attributed to leaching from vegetation. This reservoir has been used for approximately 35 years. The steep slopes of the watershed are forested largely with oak trees. The water in storage is

completely replaced each year as a result of use and runoff. For these reasons, the annual manganese content must be due to leaching from leaves.

Water from San Clemente is chlorinated and filtered. No difficulties have been experienced from the presence of manganese in the distribution system, which is served through the San Clemente filter plant. But the sand grains in the filters have taken on the appearance of smooth dark-red garnets. False orthotolidine chlorine residuals are experienced at the filter plant in late summer and fall.

The San Clemente reservoir has water flowing to waste for much of the year. With such a reservoir, it is possible to reduce the manganese concentration as well as the associated iron and color concentrations by discharging a portion of the waste water from the bottom outlet rather than by discharging it all through the spillways. In this way, treatment problems at the filter plant may be reduced.

San Ysidro

A serious problem resulting from well waters containing manganese has existed at San Ysidro, Calif. There the water supply is from wells in the Tia Juana Valley. No manganese or iron is present in the surface flow of the Tia Juana River, but the ground water contains as much as 1 ppm each of iron and manganese. No treatment of this water other than simple chlorination had been provided. Chlorine residuals were low at the point of application, and no chlorine residuals were held along the distribution system. Growths of *Gallionella* existed throughout the system and caused some complaints of dirty water. Eventually, the persistence of positive coliform findings required an increase in the chlorine dosage. Immediately after increased chlorination, the coatings fell from the pipelines, and the water became as black as ink. The cause of black water was thought to be too much chlorine. Continued chlorination and flushing, however, improved the situation.

San Vicente and El Capitan Pipelines

In January 1953, an inspection was made of the interior of the pipelines extending to San Diego from San Vicente and El Capitan in San Diego County. This inspection showed the presence of a thick chocolate-brown slime coating. Analyses of this slime revealed the presence of large amounts of manganese and iron (Fig. 1). A program of high-concentration chlorine slugging was instituted. The lines were taken out of service, treated with 50–100 ppm chlorine, and allowed to stand for 48 hr. At the end of the 48-hr contact period, the lines were opened and flushed at maximum possible velocity to remove the slime loosened or destroyed by the chlorination. This treatment was repeated at 3-week intervals—except when demand did not permit the decrease in transmission capacity—until the lines were cleaned. Inspection in July 1954 showed that cleaning had been completed. During treatment operations, samples of scrapings were taken and analyzed. These analyses showed manganese concentrations of 11–41 per cent and iron concentrations of 0.1–4.1 per cent.

Otay System

Problem. Typical "delayed-action" manganese problems were experienced in San Diego's Otay system in 1954.

The service area receiving Otay Reservoir water suddenly began to experience high turbidities, stained plumbing fixtures, and ruined laundry. By the time laboratory tests could be made, the highest turbidity encountered was 20 ppm, but it had undoubtedly been higher. Iron and manganese compounds were identified as the cause of the turbidity. All water entering the Otay service area at the time was being filtered. The filter effluent had a turbidity of about 1 ppm or less. The 24-year-old steel transmission line was 40 in. and 36 in. in diameter, with a relatively good coal-tar lining. There was no past experience to indicate that the pipe was a source of the suspended matter. The only apparent variable was that, starting in March 1954, Otay Reservoir water was augmented by an inflow of water from Barrett Reservoir. Analyses and comparison of the two waters indicated a pickup somewhere in the system, possibly due to a radical change in the water.

Inspection. The main transmission line was temporarily shut down, drained, and the interior inspected. The entire line was found to be coated with a reddish black slime that imparted a persistent stain to skin and clothing. Analyses identified the slime as a combination of manganese and iron compounds. Evidently, this slime had been stable as long as the water was stable, but as soon as the water changed, the slime readily left the pipe walls and became the observed suspended load. The original source of the slime could only be conjectured. The fact that the filters had shown no recent signs of manganese deposition led to the belief that the material had been deposited while the filters were being bypassed. The bypassing of filters had been practiced for portions of the 3 years during an extreme drought period when the level of water in the reservoir had been too low to force water through the pressure filters.

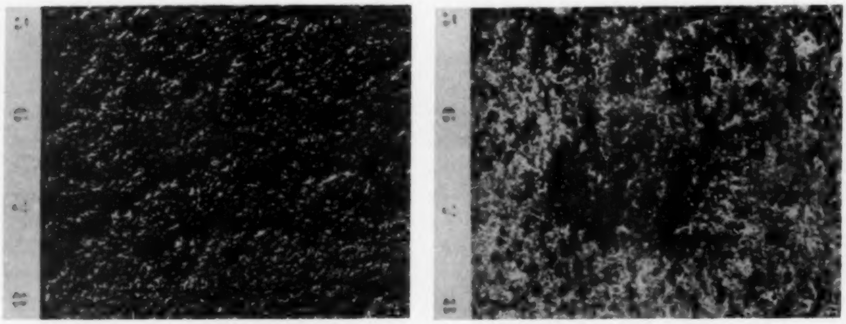

Fig. 1. Interior of San Vicente Pipeline—1953

Originally, the interior surface of the 48-in. pipeline was smooth concrete lining. The close-up of the interior on the left shows the roughness resulting entirely from manganese slimes. The photograph on the right shows the same interior after chlorine treatment. Dark areas are remains of manganese slime; light areas are virtually clean concrete. Numerals are from a tape measure in inches.

Characteristics of water. During most of the period when the filters were bypassed, the water was only moderately turbid, although the suspended organic load was sometimes excessive. The load consisted of living plankton, mainly blue-green algae. Most of the water was delivered to rural consumers and was not conducted to the city. No manganese staining was reported. One period emerged as the most likely one for the establishment of the pipeline coating. manganese concentrations, although manganese determination was not included in routine analyses. The water was chlorinated to the limit of existing equipment—60–100 lb of chlorine per 1 mil gal of water. Bacteriologic findings were generally satisfactory.

Analysis. The available evidence finally indicated the likely chain of events. Starting in July 1951, reservoir bottom water was pumped into the transmission system, chlorinated, and delivered to rural pipeline consumers. Manganese evidently was present, but only in trace or minor concentrations. Heavy chlorination caused the precipitation of manganese dioxide in the pipelines, this precipitate combining with organic matter to form an adhesive slime. It is suspected that manganese-concentrating bacteria were active in the slimes.

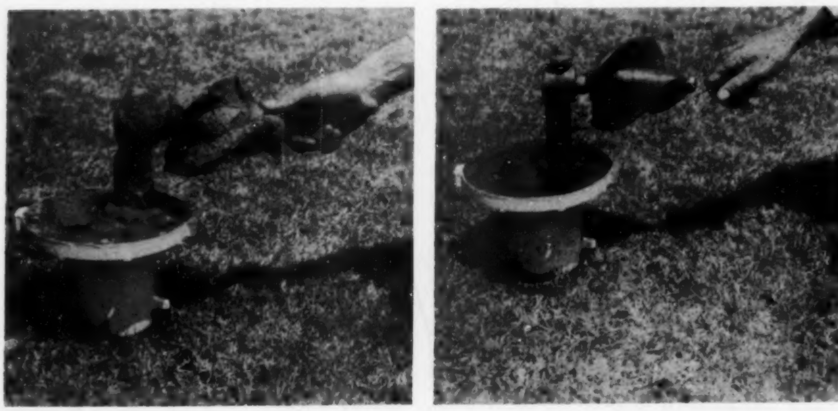

Fig. 2. Iron and Manganese Deposits on a Meter

Shown is a meter before and after cleaning. The crust was deposited by Gallionella.

In July 1951, the water level in the reservoir had fallen to the level of the lowest outlet. Because the needs of pipeline consumers still had to be met, floating pumps were installed in the reservoir and discharged into the outlet works. This continued until April 1952. The head was insufficient to permit filtering. Occasional reports of "muddy water" were received during this 10-month period, but there was no suspicion that it was anything but simple mineral turbidity. There were no signs of measurable

Slimes. The slimes remained in a stable state from the period of bottom pumping and filter bypassing for 2 years until March 1954, when the chemical characteristics of the water

suddenly changed. The chemical part of the slime-binding material evidently was broken down by the different water, and the material came off in great quantities. As soon as possible, the entire transmission system from this source was put out of service, given a heavy 48-hr soaking with chlorine solution, and flushed to waste. This effectively removed all but the traces of the slime. The effectiveness of chlorine in the removal of manganese-organic slimes had been demonstrated earlier in other pipelines serving the San Diego system. It is believed that the chlorine destroys the organic part of the slime binder, causing the manganese dioxide to separate from the pipe walls.

Past history. There is some historical evidence that manganese was present in the Otay system in earlier times. The original pressure filters were built in 1915 and filled with white

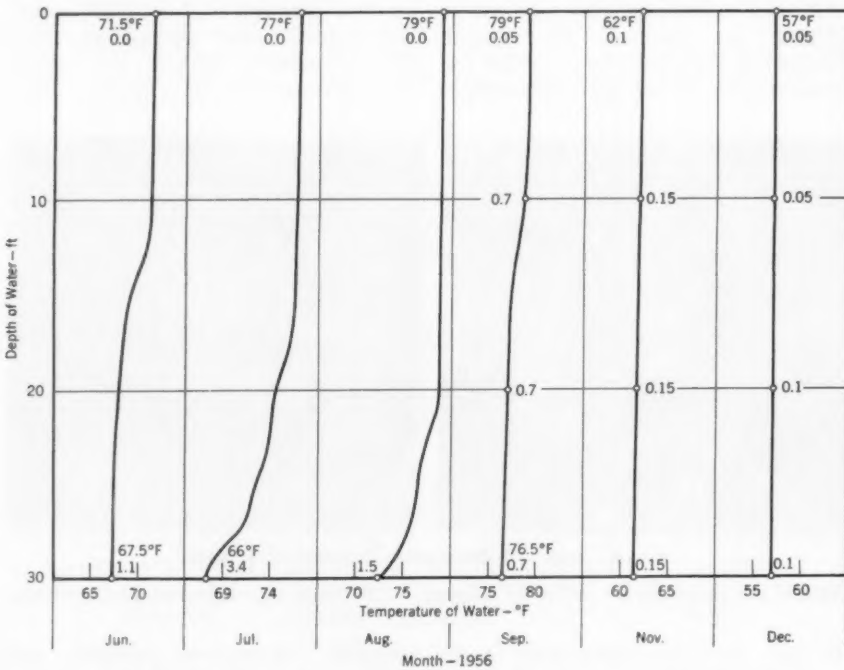

Fig. 3. Manganese Concentrations in Sweetwater Reservoir—1956

Values, other than those of temperature, on the curves pertain to manganese concentrations in parts per million.

silica sand from New Jersey. Additional filters, installed in later years, used other sands, all of them white, light gray, or light buff. In many instances, it was reported that the filter sand turned a reddish black within a matter of months. There are no quantitative data available for these early

years, but there is a strong indication that manganese dioxide was being precipitated on the filter sands.

Helix Irrigation District

The 42-in. pipeline of the Helix Irrigation District has decreased in carrying capacity from 21 mgd to 15.5 mgd. The decrease was attributed to manganese-containing slimes, composed of about 1–32 per cent manganese and about 15 per cent iron. The water is unfiltered surface water, and total chlorine residuals have varied from a trace to about 0.5 ppm.

At the Helix Irrigation District, loss in capacity of lines carrying well waters containing iron and manganese is even more spectacular than the loss in capacity of lines carrying surface waters. In lines carrying well waters, the coating is harder and more like a spongy crust, frequently mistaken for rust. Yet when the crust is removed, the pipe will be in good condition with little corrosion. Where this coating is allowed to increase, the impellers of meters at well sources become heavily coated, cutting down on the cross section area of the meter. Consequently, as the coating builds up, the meter will turn faster. Water meters at wells have been cleaned monthly at some installations. Figure 2 shows a meter before and after cleaning. The crust was deposited by *Gallionella* and consisted of iron and manganese.

Sweetwater District

Chlorine residuals. The measurement of chlorine residuals by the orthotolidine method at the Sweetwater District is frequently affected by manganese throughout the district's distribution system. It is believed that the importance of manganese interference in the determination of chlorine residuals is often overlooked in other places. Because oxidized manganese produces a flash color with orthotolidine—a color similar to that produced by chlorine—it is quite possible to be deceived unless proper precautions are taken. Perhaps some of the indicated high chlorine residuals that fail to produce a water free of coliform organisms are not actually as indicated. Observations by the author indicate that the erratic presence of manganese makes it advisable to use always the orthotolidine-arsenite (OTA) method in measuring chlorine residuals. It has been found that residuals of 0.2 ppm and 0.3 ppm measured by the orthotolidine method are entirely false and are due to manganese.

Shortly after the fall turnover at the Sweetwater Reservoir, when manganese is brought to the surface and into the distribution system, false chlorine residuals as high as 1.4 ppm have been experienced. For about 9 months of the year, manganese does not interfere with determinations of chlorine residuals along the transmission line from the Sweetwater Reservoir, although interference may occur in the more remote portions of the distribution system. During the other 3 months, interference may vary from slight to intense, and the intensity of interference varies widely from place to place. Because of such experiences, the OTA method is used at all times. Readings are made at each place where a bacterial sample is taken. The information is recorded along with the coliform findings.

Reservoir conditions. The appearance of manganese near the surface at Sweetwater Reservoir has been the cause of periodic complaints of colored and muddy water. The water from Sweetwater is unfiltered, but a modern 25-mgd filter plant is now being

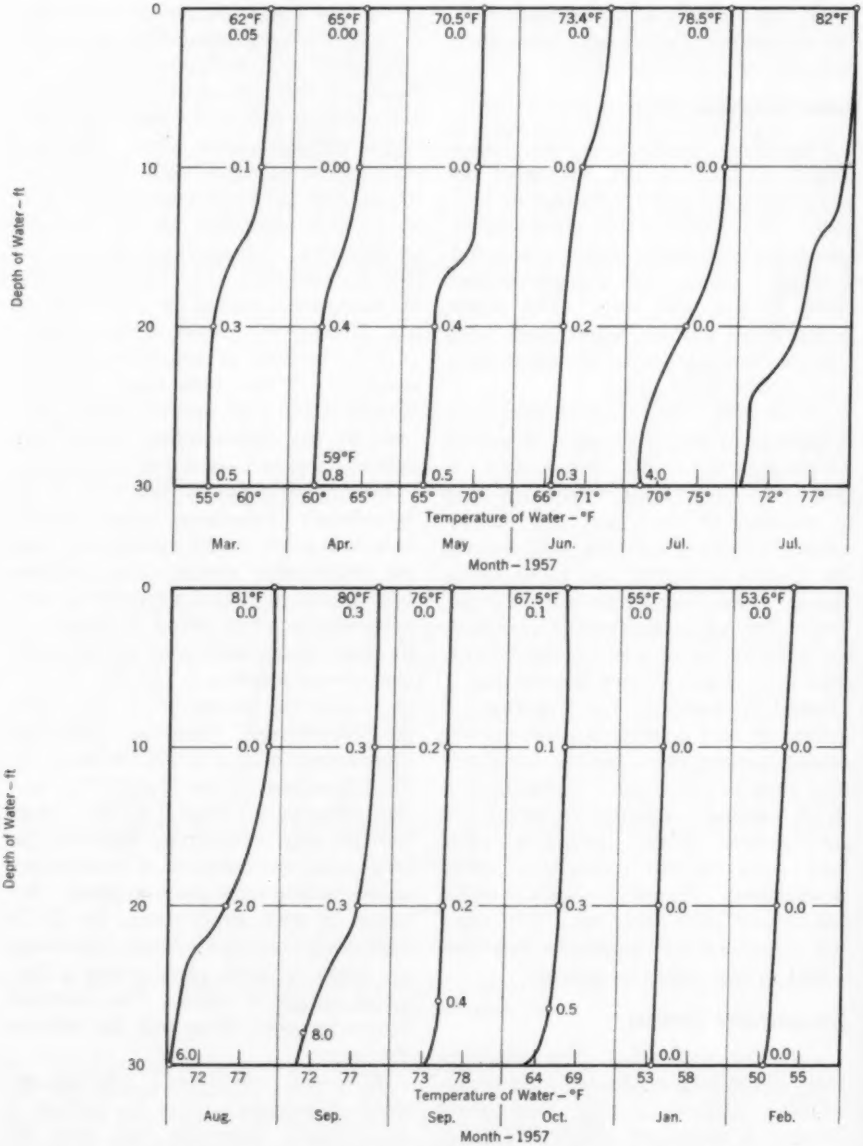

Fig. 4. Manganese Concentrations in Sweetwater Reservoir—1957

Values, other than those of temperature, on the curves pertain to manganese concentrations in parts per million. Curves for July and September are repeated in order to show that unexpected variations in the thermocline may occur.

constructed. Until 1948, the impounded water was entirely from local runoff. Since 1948, the water has consisted of varying mixtures of Colorado River water and local runoff. The depth of water in the reservoir varies widely from year to year. Free residual chlorination has been practiced, and, because of this, any appreciable manganese concentration has shown up at once. The chlorinated water turns to a tea color.

Prior to the use of free residual chlorination, there was no information on manganese concentrations at Sweetwater. Chemical analyses were made two or three times each year on samples taken from the surface. The samples had never shown the presence of manganese. They had been taken at times before or long after the lake overturn. Each year, however, the bell jars in the chlorinators had, from time to time, been stained with a dark-brown coating of manganese. The discolored water in the transmission lines had been attributed to the unfiltered supply and iron rust from the mains. After the mains were cement lined, complaints of discolored water continued, and it was apparent that manganese and iron were coming from Sweetwater. The cement lining turns brown. When wet, it has a slimy feeling. The film is only paper thin and becomes powdery when dry. This coating consists of iron and manganese held together by an organic binder. None of the iron bacteria has been observed. As a free chlorine residual of not less than 0.6 ppm is maintained at all times, bacterial slimes do not exist.

Chemical characteristics. Investigations during the past few years have shown that the source of manganese is the lake bottom. The element is always associated with a much higher iron concentration. The iron and manganese concentrations increase with depth (Fig. 3 and 4), and the elements are seldom present in water near the surface. Although water is never taken directly from the surface into the distribution system, manganese and iron may be entering the system when surface samples fail to indicate their presence. Concentrations of these elements below the thermocline increase steadily during the portion of the year when the circulation in the lake is horizontal. Sweetwater Reservoir is in a state of continuous vertical circulation from late fall to spring. During this time there is no thermocline, and dissolved oxygen is carried deep in the water. In the early spring, surface temperatures increase, and a well defined thermocline develops. At this time, typical changes in chemical characteristics above and below the thermocline become pronounced. Chemical stratification becomes intensified during the portion of the year when the reservoir is in a state of horizontal circulation. Below the thermocline, the pH is low; the calcium concentration is higher than near the surface. The surface pH may be as high as 9.0. At this pH, calcium carbonate precipitates, only to be redissolved as it settles below the thermocline. Below the thermocline, hydrogen sulfide and nitrite nitrogen are present. Iron and manganese concentrations become quite high, because dissolved oxygen disappears below the thermocline, and reducing conditions exist. These elements are leached from the bottom sediments.

Physical characteristics. In the late summer, the differences between day and night temperatures are greatest. The nights are cool, and the reservoir surface radiates more heat than is re-

ceived during the day. Consequently the water temperature above the thermocline begins to drop. The surface water becomes a little denser, and the lake becomes thermally unstable. Eventually this results in an overturn, and the reservoir begins its stage of vertical circulation. The overturn occurs in a matter of hours and is easily recognized because of a sudden drop in surface temperature as well as pH. The reservoir takes on a brownish cast and transparency decreases. It is at this time that manganese reaches the surface.

Occasionally a high wind will impart enough energy to the reservoir to cause an overturn. In such instances, there may be more than one overturn per year. Often the type of overturn described here is overlooked. There is a tendency to attribute the long periods of stagnation and the complete isolation of the hypolimnion from the surface water only to the northern colder waters.

The manganese concentration after reservoir turnover is never the same for different years. This is easily explained by a comparison of the volumes of water above and below the thermocline. If the reservoir is full, much of the volume is above the thermocline; although manganese is present high in the hypolimnion, the dilution by manganese-free water is great. Consequently, when Sweetwater Reservoir is full, little trouble is experienced from manganese after turnover. But if the reservoir is low, there is not much top water to dilute the manganese-containing water, and problems are to be expected.

Another observation regarding the thermocline at Sweetwater is that its depth varies throughout the day at the outlet tower. Each reservoir has a typical circulation pattern determined by reservoir form, prevailing winds, and depth and temperature of the water. The prevailing winds at Sweetwater are from the west. The outlet is near the dam and also at the west end of the reservoir. Consequently, the depth of the epilimnion at the outlet may vary as much as 10 ft during a summer day. The behavior of the thermocline in the reservoir is comparable to the behavior of a layer of oil on water in a long pan that is continually tilted up and down. Because of knowledge of this behavior, it may be stated that water is always withdrawn far enough above the thermocline to avoid the withdrawal of manganese, which is more prevalent below the epilimnion. It is interesting to note that just above the thermocline the highest concentration of many plankton organisms such as *Ceratium* is found.

Conclusions. The observations at Sweetwater have made it possible to reduce the number of days of manganese problems in the distribution system. It has also been possible to predict when manganese problems are likely to occur.

Acknowledgments

The author expresses his appreciation to John A. Carollo, consulting engineer; Roy E. Dodson Jr., water superintendent, San Diego Utilities Department; and L. L. Flor, chemist and supervisor of water quality, Helix Irrigation District, for the information they have made available.

Electrophoretic Studies of Coagulation for Removal of Organic Color

A. P. Black and Donald G. Willems

A contribution to the Journal by A. P. Black, Research Prof. of Chemistry & San. Science, Dept. of Chemistry, Univ. of Florida, Gainesville, Fla.; and Donald G. Willems, San. Engr., State Board of Health, Helena, Mont. *The investigation was supported by Research Grant RG-4516 from the National Institutes of Health, USPHS, and by a traineeship (59-337) from USPHS.*

ORGANIC color is a fairly common constituent of many natural waters. The materials causing color in water are not known to be injurious to health, but color is reduced for aesthetic reasons. The 1946 USPHS Drinking Water Standards [1] recommend for public water supplies a maximum color concentration of 20 on the platinum-cobalt scale. Most municipalities, however, endeavor to maintain lower concentrations, on the order of 10 or even less. Many industrial users, of which the pulp and paper industry is possibly the best example, require waters with low concentrations of color. For the production of high-brightness bleached pulp and paper, the maximum concentration of color tolerated is usually 5 or less.

In many areas of the United States where the prevailing aquifers are limestones and where solution-type topography permits high recharge of surface water, considerable concentrations of organic color may be present in water from both deep and shallow wells. In such instances, lime-soda softening has been shown to remove a substantial amount of the color, particularly in waters with high concentrations of magnesium. The concentration of organic color in water from more than twenty wells supplying the Hialeah plant at Miami, Fla., is reduced to 5–8 by lime softening followed by free residual chlorination. Organic color, however, is more characteristic of soft surface waters of low alkalinity and, consequently, of low buffer capacity.

The most common method of color removal consists of coagulation with alum or ferric salts, usually in the acid range. Extensive jar tests are usually required to determine the optimum dosage of coagulant and the optimum pH for the desired color reduction. Coagulation in the pH range 5.2–5.7 has yielded excellent results with many waters, but many other optimum pH values have been reported in the literature. Waters having similar chemical characteristics and color values often require quite different treatments for best results.

Nature of Organic Color

The problem of color removal is made more difficult by the fact that very little is known about the exact nature of the compound or compounds that constitute organic color in water. Saville,[2] in a much quoted article, after

using the crude electrophoretic techniques of his day, reported that most, if not all, of the organic color present in water is in the form of a negatively charged colloid. Several years later, Behrman, Kean, and Gustafson [3] attempted to answer the following questions with respect to organic color in water:

1. What is the chemical constitution of color bodies?

2. Are color bodies present as colloids or are they in true solution?

3. Are color bodies readily oxidized and degraded?

4. Are color bodies organic or may they be in part inorganic in nature?

Using tea extract and solutions of alkaline pyrogallol, Behrman, Kean, and Gustafson found that the particles of these materials were negatively charged, but they made no observations on the color present in natural water. They found that little of the natural organic color in water would dialyze through a parchment membrane, indicating the colloidal nature of the color. They believed it to be organic in nature, because the chemical oxygen demand of natural water from which the color had been previously removed by coagulation was significantly less than before removal of the color. They found that the color bodies act as indicators, decreasing in intensity at low pH values and increasing in intensity at high pH values. Finally, they found that most of the color could be oxidized by chlorine. None of these studies, however, gave any information with respect to the exact chemical nature of the color substances present in natural waters.

Delong and Schnitzer [4] reported that leaf extracts and solutions from forest canopies and forest floors are "capable of the mobilization and transportation of iron" and believed that the active material in these extracts is an "acidic polysaccharide." Okura and Goto [5] stated that the oxidation of iron is retarded by "humic substances," a term that is frequently found in the literature to describe the organic material derived from organic matter in soils, forests, and swamps. Hem,[6] in his studies of the complexing of ferrous iron with tannic acid, stated that:

> Tannic acid is obtained commercially from galls of oak, sumac, and willow, and occurs in green algae, mosses, brown sea weed, ferns, pore fungi, and in about one-third of the families of flowering plants. The behavior of ferrous and ferric iron in solutions containing tannic acid may be analogous to their behavior in natural water that contains organic extracts.

Shapiro [7] reported the results of an elaborate study of the yellow organic acids in the water from nine lakes in Connecticut, one in New York, and one in Wisconsin. Large samples of water were evaporated *in vacuo,* temperatures never exceeding 45°C, and the dried residues acidified and extracted with various organic solvents. After further treatment, paper chromatograms were run and photographed by long-wave ultraviolet light. Various types of absorption spectra were also obtained. Shapiro concluded that the organic color in water consists mainly of ultraviolet-fluorescing dicarboxylic hydroxy aliphatic organic acids, with a molecular weight of approximately 450. He concluded that the sharp zones obtained in his chromatograms were due to various metallic salts of these acids. He believed that if aromatic rings are present, as has long been implied by use of the term "tannic acid color," they are probably relatively unimportant. Shapiro found

the materials to be quite stable. Organic extractions of the residue from freshly collected water were found to be identical with those of the same water allowed to stand unfiltered and in the light for 4.5 months before evaporating. Further, although refluxing with acid permanganate for 2 hr destroyed the color and fluorescence, it did not affect the infrared absorption spectrum. Finally, and most important of all, he found that the salts of the acids are dialyzable through cellophane membranes, indicating that they are not colloidal.

TABLE 1

Partial Chemical Analyses of Two Colored Waters

Constituent	Water A	Water B
	Concentration of Constituent—*ppm*	
Total dissolved solids	30	90
Calcium ion	3.2	8.4
Magnesium ion	1.9	6.0
Bicarbonate ion	6.1	23
Chloride ion	6.0	30
Alkalinity (as $CaCO_3$)	5.0	19
Total hardness (as $CaCO_3$)	16	45
Organic color	270	225

It was the primary purpose of the investigation reported herein to study the change in the mobility of floc particles during the coagulation of two highly colored surface waters with alum and ferric sulfate in the hope that the data obtained might contribute to a better understanding of the basic mechanisms of coagulation.

Experimental Procedures

Two highly colored surface waters were used in these studies. Partial chemical analyses are given in Table 1. It will be noted that, although both waters have high concentrations of organic color, Water A is quite low in total solids and has an alkalinity of only 5.0 ppm; whereas Water B, although not highly mineralized, contains three times as much total solids and has an alkalinity of 19 ppm.

Water A was obtained from a small creek draining a typical Florida hammock forest that contained swamps with underlying peat deposits. Water B was obtained from a much larger creek, about 40 mi away, but one with about the same forest cover.

For alum coagulation, reagent grade aluminum sulfate with a chemical formula of $Al_2(SO_4)_3 \cdot 18H_2O$ was used. Reagent grade ferric sulfate with a chemical formula of $Fe_2(SO_4)_3 \cdot xH_2O$ and containing 72 per cent $Fe_2(SO_4)_3$ was used in the ferric sulfate experiments. For the jar tests, a stirring machine accommodating six jars was used. One-liter samples of water were placed in the 1,500-ml square jars, and the samples were stirred for 2 min at a paddle speed of 100 rpm while the chemicals were being added. At the end of the 2-min rapid-stirring period, paddle speed was reduced to 20 rpm, and stirring continued for an additional 20 min for optimum floc formation. At the end of the flocculation period, the stirrers were stopped, the size of the floc was noted, and floc settling characteristics were observed. A solution of 0.1*N* HCl and a saturated lime solution were used for pH adjustment when required by the experiment. Color was determined with a colorimeter * equipped with a 420-mμ filter employing a standard curve derived from the measurement of

* Lumetron Model 450, made by Photovolt Corp., New York, N.Y.

platinum-cobalt color standards. Samples were filtered through No. 615 filter papers before color determinations were made, and the pH was measured.* Particle mobilities were determined by electrophoretic measurements in the Briggs cell, by use of the apparatus and techniques described by Pilipovich, Black, Eidsness, and Stearns.[8] As zeta potential is directly proportional to mobility, and as small undeterminable changes will occur in the viscosity and the dielectric constant, mobility values are used in place of calculated zeta potentials in interpreting experimental data. An approximate value for the zeta potential, expressed in millivolts, may be obtained by multiplying the mobility value by 13.

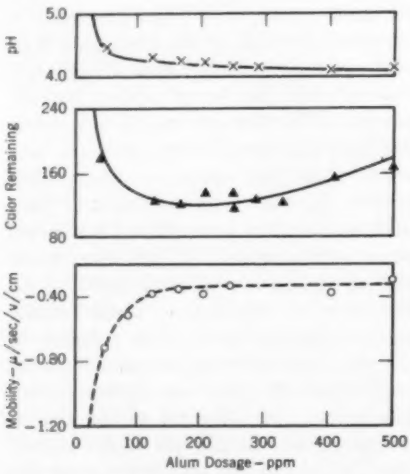

Fig. 1. Effect of Alum Dosage on Coagulation of Water A

The curves show the effect of alum dosage on floc mobility, color removal, and pH. Although good flocs formed in many of the jars, color removal was poor, the best sample having a residual color of 120.

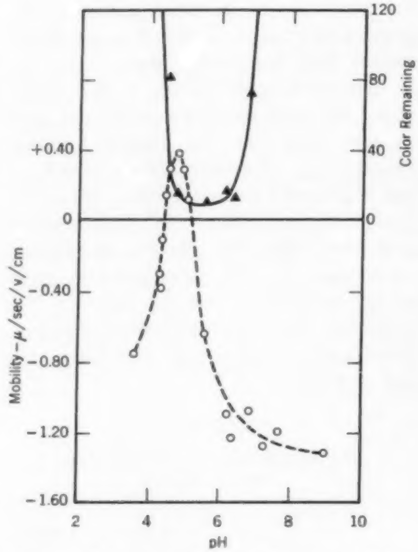

Fig. 2. Effect of pH and Constant Alum Dosage on Coagulation of Water A

A constant alum dosage of 120 ppm was employed, and the pH was adjusted with $Ca(OH)_2$.

Coagulation of Water A With Alum

Figure 1 shows the results of the coagulation of Water A with alum, up to a maximum dosage of 500 ppm. The top curve gives pH values; the middle curve, residual color; and the bottom curve, the measured mobility of the floc particles. Although good flocs formed in many of the jars, color removal was poor, the best sample having a residual color of 120. All floc mobilities were negative and decreased sharply with the low alum dosages, the mobility curve leveling off at an alum dosage of 120 ppm. All pH values were less than 4.5.

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* The meter used was a Model G pH meter, manufactured by Beckman Instruments, Fullerton, Calif.

Figure 2 shows the dramatically different results that were obtained by employing a constant dosage of 120 ppm alum and adjusting the pH with $Ca(OH)_2$. The upper curve identifies a relatively narrow zone of excellent color reduction between about pH 5.0 and 5.7. The mobility curve shows that as the pH increased, the negatively charged floc particles became positively charged slightly before the pH zone of optimum coagulation and again reversed their charge almost exactly at the beginning of the pH zone of optimum coagulation, after which they rapidly became more negative as pH increased.

Figure 3 shows the results obtained with alum dosages of 20–120 ppm, but with the pH maintained constant at 4.85 by the addition of HCl and $Ca(OH)_2$. Color reduction increased with increasing alum dosages, the curve flattening out at about 90 ppm alum. The particle mobility curve is fairly symmetrical with the color reduction curve, and charge reversal occurred almost exactly at the first point of optimum color removal.

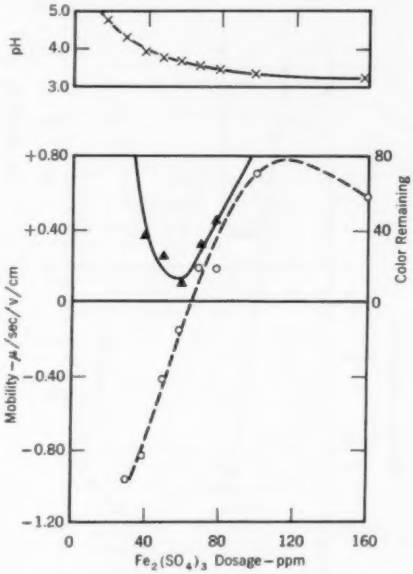

Fig. 4. Effect of Ferric Sulfate Dosage on Coagulation of Water A

Water A was successfully coagulated with $Fe_2(SO_4)_3$ without the addition of alkalinity.

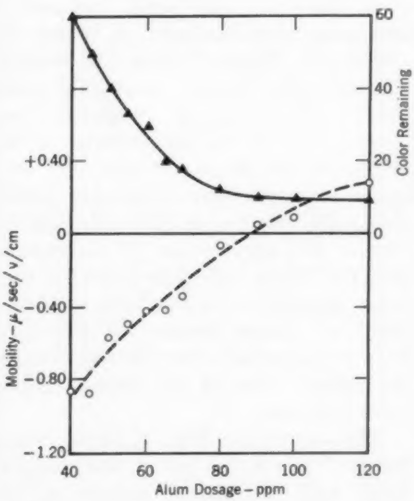

Fig. 3. Effect of Alum Dosage and Constant pH on Coagulation of Water A

The pH was maintained constant at 4.85 by the addition of HCl and $Ca(OH)_2$.

Coagulation of Water A With Ferric Sulfate

In sharp contrast to the foregoing results, Water A was successfully coagulated with $Fe_2(SO_4)_3$, without the addition of alkalinity. Figure 4 shows floc mobilities, color remaining, and pH values for ferric sulfate dosages of 30–160 ppm. There is a well defined, narrow zone of optimum color removal between pH 3.4 and 3.7; the lowest

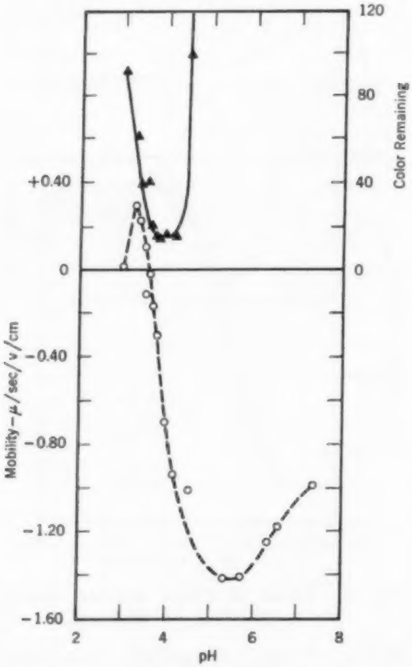

Fig. 5. Effect of pH and Constant Ferric Sulfate Dosage on Coagulation of Water A

A constant $Fe_2(SO_4)_3$ dosage of 60 ppm was employed, and the pH was varied with HCl or $Ca(OH)_2$.

point of the curve coincides almost exactly with the pH at which the floc particles reversed their charge from negative to positive. In Fig. 5, the water was coagulated with a constant dosage of 60 ppm $Fe_2(SO_4)_3$; the pH was varied in the range of 3.0–8.0 with HCl or $Ca(OH)_2$. As the pH increased from 3.0 to 5.7, the floc particles became slightly positive, then reversed their charge and rapidly became more negative to about pH 5.7, after which they became less negative. There is a very narrow zone of optimum color removal at pH 4.0–4.6, within which floc charge changed from slightly positive to slightly negative. In Fig. 6, the same water was coagulated with dosages of 20–120 ppm $Fe_2(SO_4)_3$, the pH being held constant at pH 3.55 in one series of tests and at pH 3.90 in a second series. Although color removal was poor at pH 3.55, the best color removal was obtained with that dosage of $Fe_2(SO_4)_3$, 50 ppm, which produced neutral floc particles. At pH 3.90, $Fe_2(SO_4)_3$ dosages of 50–120 ppm gave good color removal. The points of inflection of the color removal and mobility curves coincide; and during the dosage range producing low color values, all floc particles carried about the same slight negative charge.

Coagulation of Water B With Alum

An identical series of jar tests was performed with Water B, which had three times the total solids and about four times the alkalinity of Water A (Table 1). Figure 7 shows the results obtained with dosages of 20–300 ppm alum, with no added alkalinity. In sharp contrast to the results with Water A, floc formation and color removal were excellent. The floc particles, quite negative at pH 6.80, rapidly became less negative as pH decreased, and the sharp inflection point of the color removal curve coincides with the point of charge reversal at pH 5.0. Floc particles had a low positive charge throughout most of the zone of good color removal.

The curves in Fig. 8 show what resulted when the water was coagulated with a constant dosage of 60 ppm alum and the pH varied from 4.0 to 9.0 with HCl and $Ca(OH)_2$. Water B behaved in general like Water A (Fig. 2), except that the alum dosage required for good coagulation was lower, and, possibly because of that

fact, no definitely positive floc particles were obtained in any jar. But the narrow zone of good coagulation and optimum color removal between pH 5.2 and 5.7 was almost exactly the same as for Water A and coincided in part with the pH zone within which floc particles are uncharged.

Figure 9 shows curves for Water B coagulated with dosages of 20–80 ppm alum, with pH held constant at 5.25. In general, the curves resembled those for Water A (Fig. 3), except that color removal was not quite as good, and no positively charged floc particles were observed.

Coagulation of Water B With Ferric Sulfate

Like Water A, Water B was successfully coagulated with $Fe_2(SO_4)_3$ without added alkalinity. Figure 10 shows the results obtained by coagulating Water B with dosages of 20–180 ppm $Fe_2(SO_4)_3$. There was a fairly narrow zone of optimum color removal between pH 3.5 and 3.9, within which floc particles reversed their charge from negative to positive, and flocs producing fair color reduction at higher coagulation dosages and lower pH values bore weakly positive charges.

Figure 11 shows the results of coagulating Water B with a constant dosage of 50 ppm $Fe_2(SO_4)_3$ and adjusting the pH with HCl and $Ca(OH)_2$ to values of 3.0–10.0. The results are quite similar to those obtained by coagulating Water A (Fig. 5) with 60 ppm $Fe_2(SO_4)_3$. There is a narrow zone of optimum color removal between pH 3.8 and 4.5, within

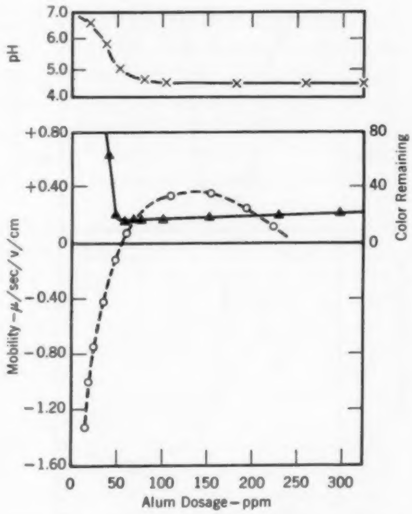

Fig. 7. Effect of Alum Dosage on Coagulation of Water B

In contrast to the results obtained with Water A, floc formation and color removal were excellent. The higher alkalinity of this water provides the higher pH values needed for hydrolyzing the alum without the addition of $Ca(OH)_2$.

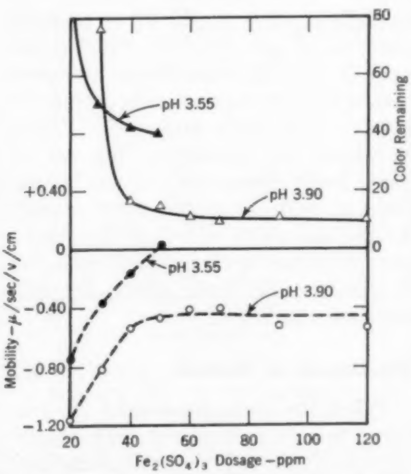

Fig. 6. Effect of Ferric Sulfate Dosage and Constant pH on Coagulation of Water A

The pH was held constant at 3.55 in one series of tests and at 3.90 in a second series.

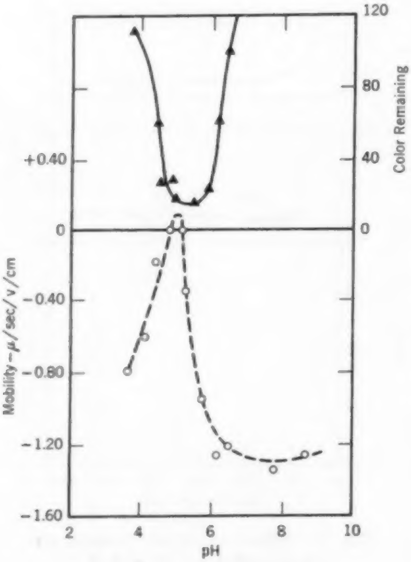

Fig. 8. Effect of pH and Constant Alum Dosage on Coagulation of Water B

A constant alum dosage of 60 ppm was employed, and the pH was varied with HCl and $Ca(OH)_2$. Although the mobility curve is shown with a small positive loop, actually no definitely positive particles were found in any jar.

which floc charge changed from slightly positive to slightly negative.

The curves in Fig. 12 were obtained when the water was coagulated with dosages of 20–60 ppm $Fe_2(SO_4)_3$ and the pH held constant at 3.85. The results were in general the same as those obtained with Water A. Floc mobilities became less negative, and color removal improved as coagulant dosage was increased. The dosage that resulted in optimum color removal produced a floc whose particles exhibited almost no movement in the electrophoresis cell.

Coagulation With Cationic Polyelectrolyte

Cohen[9] found that a strongly cationic coagulant aid could partly or entirely replace alum for certain types of waters. An investigation of whether a cationic polyelectrolyte coagulant aid might fulfill all the conditions required for the coagulation of a water containing organic color was believed to be of interest. Accordingly, the same cationic aid studied by Cohen was used, and a series of jar tests was run using it as the sole coagulant. The dosages employed would be uneconomical in water treatment practice, but they were necessary in order to study the behavior of the coagulant aid. The aid was found to be fairly effective for color removal, but only in the acid range. Figure 13 shows the results of coagulating Water A with dosages of 60 ppm and 80 ppm of the aid. Floc mobilities changed from strongly positive at pH 3.0 to strongly negative at pH 6.5–7.0. Final colors were 26 and 22, respectively, and were obtained at the approximate isoelectric points of the flocs produced. Figure 14 shows the results of the use of much lower dosages of the aid in conjunction with alum and ferric sulfate. As the dosage of added aid increased, floc mobilities reversed from negative to positive, but little effect on color removal was found.

Discussion of Results

When the foregoing results are analyzed, two facts stand out very clearly: (1) electrophoretic measurements indicate that, with regard to the two waters used, optimum coagulation and color removal with both alum and ferric sulfate were accompanied by reversal

of the zeta potential of floc particles from negative to positive and that, within the pH zone of good coagulation, the zeta potential of floc particles, whether negative or positive, was quite low; (2) the pH zone of good coagulation with ferric sulfate was substantially lower than the corresponding pH zone of good coagulation with alum, and, within this low pH zone where ferric sulfate is most effective, alum was ineffective.

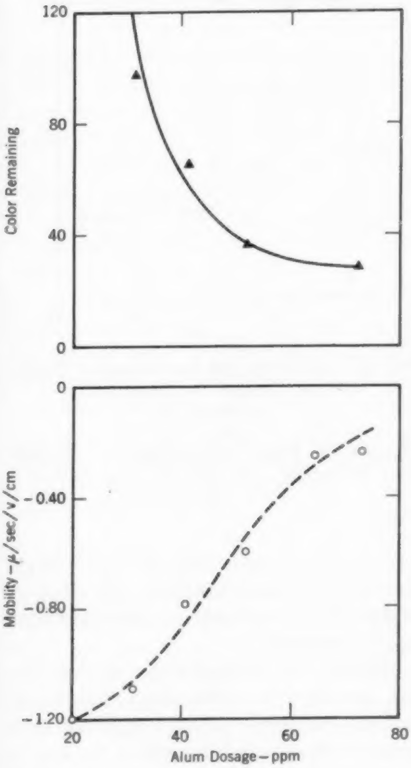

Fig. 9. Effect of Alum Dosage and Constant pH on Coagulation of Water B

The pH was held constant at 5.25. Although the pH employed was well within the pH range in which alum hydrolyzes, the maximum alum dosage used was not sufficient to reduce the color to an acceptable value.

Miller,[10] in his study of the clarification of colored waters, concluded:

> In the clarification of the colored waters studied, it is the strong coagulating power of the trivalent aluminum ion acting upon the negatively charged colloidal "color" which is of importance. It causes the formation of what may be called a "color floc." "Alum floc," which is of so much importance in other aspects of clarification, plays an unimportant role. In fact, the formation of "alum floc" by its removal of aluminum ion from solution in the form of an insoluble compound would be antagonistic to the formation of the "color floc." All conditions, therefore, such as proper hydrogen ion concentration, which would otherwise tend to retain the aluminum in solution in the form of aluminum ion, will tend to promote coagulation of these "colors."

In spite of the foregoing, all data in this article are consistent with the assumption that the hydrolysis products of alum and ferric sulfate are more effective than the respective trivalent metal ions in reducing or reversing the zeta potential of floc particles. If Schulze's rule were followed and the trivalence of the aluminum ion were the primary factor, then alum should coagulate Water A better than Water B, whereas the reverse was true. The behavior of the two waters toward alum and ferric sulfate, respectively, can be explained when it is remembered that, as Miller[11, 12] long ago showed, ferric sulfate will hydrolyze within a pH range more than one full pH unit lower than the range within which alum hydrolyzes. He showed

that, whereas practically all the iron is precipitated by NaOH from a $0.01M$ solution of ferric alum below pH 4.0, precipitation of aluminum by NaOH from a $0.005M$ solution of potassium alum does not approach completion until about pH 5.4. The pH values observed in this study indicate, therefore, that hydrolysis products of ferric sulfate were formed in both waters without the addition of any form of alklalinity, whereas with regard to alum, hydrolysis products were not formed without the addition of alkalinity in Water A but could and did form without added alkalinity in Water B. Pilipovich and others [8] and Black and Hannah,[13] in their studies of the coagulation of clays with alum, have

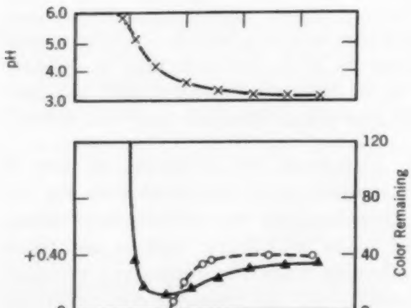

Fig. 10. Effect of Ferric Sulfate Dosage on Coagulation of Water B

Like Water A (Fig. 4), Water B was successfully coagulated with $Fe_2(SO_4)_3$ without added alkalinity.

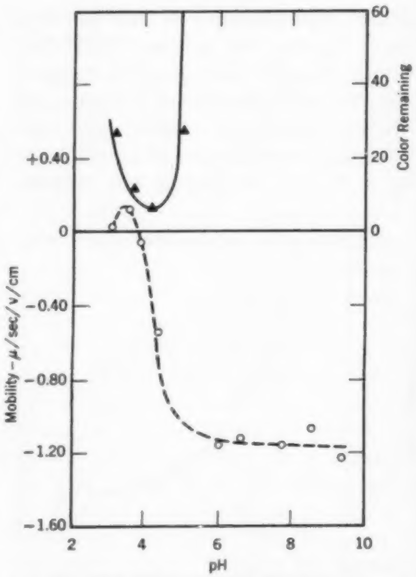

Fig. 11. Effect of pH and Constant Ferric Sulfate Dosage on Coagulation of Water B

A constant $Fe_2(SO_4)_3$ dosage of 50 ppm was employed, and the pH was adjusted with HCl and $Ca(OH)_2$.

likewise reported that the hydrolysis products of alum are most effective in reducing or reversing the zeta potential of floc particles.

Miller [11, 12] showed that the hydrolysis products of both alum and ferric sulfate are basic sulfates of fairly uniform composition throughout the major part of the pH range within which hydrolysis takes place. Figure 15 shows the highly buffered region between pH 4.4 and 5.4 within which most of the aluminum was precipitated by NaOH from $0.005M$ potassium alum, and shows that the mole ratio, $Al:SO_4$, was almost constant during that pH range. It is very important to this discussion to note that the inflection point of the curve for alumi-

num at the left in Fig. 15 is at about pH 5.4, and that the inflection point of the aluminum curve at the right in Fig. 15 is at approximately pH 8.2–8.4.

Figure 16 shows the potentiometric titration curve of a solution containing 100 ppm alum with 0.01*N* NaOH solution. The flat, buffered region between pH 4.4 and 5.4 coincides with the left curve (from Miller [11]) in Fig. 15. The first inflection points of both curves are at about pH 5.4; the unbuffered region between pH 5.4 and 7.5 is duplicated in both curves; and, finally, the second inflection points of both curves are in very close agreement, about pH 8.0 in Fig. 16 and about pH 8.2 in Fig. 15.

In recent years, colloid chemists studying the basic mechanisms of coagulation have tended to distinguish between two different mechanisms that are believed to be involved. The first is termed "perikinetic" or "electrokinetic" coagulation and is that phase of the overall process during which the zeta potential of the colloid is reversed, neutralized, or reduced by ions or colloids of opposite charge to a point where the London–Van der Waals attractive forces become predominant and primary coagulation takes place. In the second phase, termed "orthokinetic" coagulation, these primary micelles aggregate, sometimes with and sometimes without the help of a coagulant aid, to form the larger clumps or aggregates that the water chemist characterizes as "floc." It is not necessary that the zeta potential of the colloidal particle be neutralized or reversed for either electrokinetic or orthokinetic coagulation to take place. If it is reduced below 20–30 mv, depending on the colloidal system, London–Van der Waals forces become predominant, and primary micelles are formed.

Suggested Mechanisms

The following explanation of the basic mechanisms involved in color or turbidity removal by coagulation with alum or ferric sulfate is consistent with

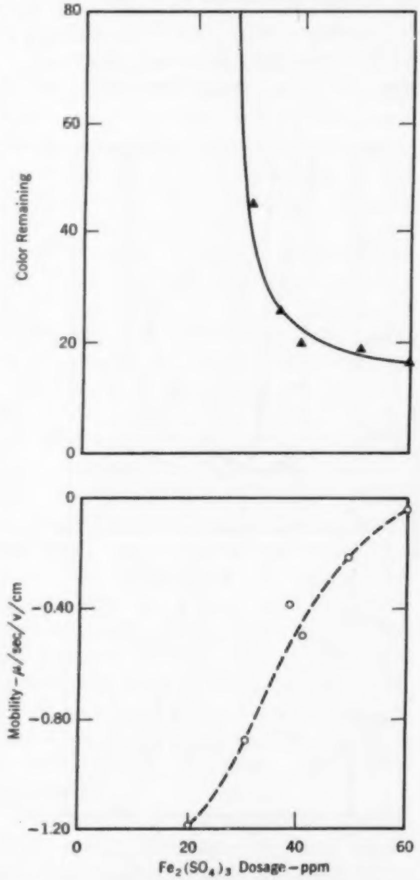

Fig. 12. Effect of Ferric Sulfate Dosage and Constant pH on Coagulation of Water B

The pH was held constant at 3.85. Although the pH employed was well within the pH range in which $Fe_2(SO_4)_3$ hydrolyzes, the maximum dosage used was not sufficient to reduce the color to an acceptable value.

what has been stated before and with the experimental data. When alum or ferric sulfate is added to a colored or turbid water whose alkalinity, naturally present or added, is sufficient to produce a pH value within the upper portion of the pH range of hydrolysis *of the respective salts,* positively charged colloidal micelles—chemically basic sulfates of the respective salts—are

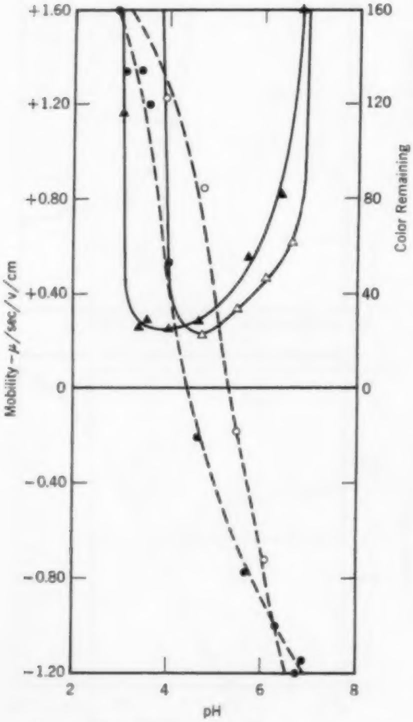

Fig. 13. Effect of High Dosages of Coagulant Aid on Water A

Open circles represent mobility at 80-ppm dosage of aid; open triangles, color remaining at 80-ppm dosage. Solid circles represent mobility at 60-ppm dosage of aid; solid triangles, color remaining at 60-ppm dosage.

formed. These positively charged hydrosols reduce or neutralize the negative charge on the colloidal particles of color or turbidity, resulting in primary or electrokinetic coagulation. Contrary to a belief that has persisted for many years, the trivalent aluminum and ferric ions probably play a relatively unimportant role in the overall process. Numerous electrophoretic measurements by the authors and others have shown that these colloidal micelles do form in solutions of the pure salts and that they are positively charged, the positive charge probably being a residual charge resulting from the loss of some of the sulfate ions by electrolytic dissociation. In the coagulation of colored waters, the zeta potential of the primary colloidal micelles—sometimes slightly negative and sometimes slightly positive—is so low that the London–Van der Waals forces of attraction are operative at the relatively low pH value of the water, orthokinetic coagulation takes place, and settleable flocs are formed. The situation is quite analagous to the volumetric titration of chloride ion with silver nitrate, for example, where the colloidal micelles of silver chloride are negatively charged owing to adsorption of excess chloride ions; become progressively less negative as the endpoint is approached; coagulate with the formation of large, curdy flocs, very slightly before the stoichiometric endpoint is reached; and, if the slightest excess of silver nitrate has been added, adsorb the silver ion and become positive.

For the coagulation of turbid waters, however, a different mechanism is visualized. The primary or electrokinetic phase consists of two types of interaction, operating simultaneously. The first is the adsorption of trivalent

aluminum or ferric ions into the lattice structure of the clay particles by ion exchange, resulting in a reduction in the negative zeta potential of the clay particles. The second is further reduction of the zeta potential of the particles by the positively charged hydrolysis products of the coagulant, similar to that which takes place with the negatively charged particles of organic color. The net result is a zone of definite but poor electrokinetic co-

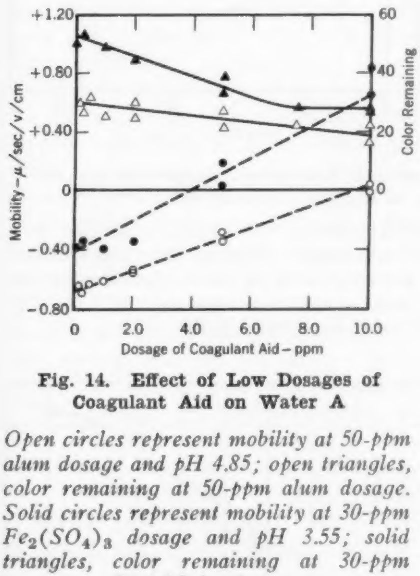

Fig. 14. Effect of Low Dosages of Coagulant Aid on Water A

Open circles represent mobility at 50-ppm alum dosage and pH 4.85; open triangles, color remaining at 50-ppm alum dosage. Solid circles represent mobility at 30-ppm $Fe_2(SO_4)_3$ dosage and pH 3.55; solid triangles, color remaining at 30-ppm $Fe_2(SO_4)_3$ dosage.

agulation in the acid range, within which the colloidal micelles are usually slightly negative. When the dosage of aluminum ion (and presumably ferric ion) is several times larger than the exchange capacity of the clay turbidity, the zeta potential of the particles is reversed from negative to positive over a fairly wide range of increasing pH values. This pH range of charge reversal for a given alum dosage, widest for clays of low exchange capacity and narrowest for those of high exchange capacity, identifies a zone of poor or no coagulation. As the pH is still further increased, the floc particles again become negative, and the hydrated oxide resulting from the hydrolysis of the aluminum ion not used up by ion exchange acts as the "binder alum" postulated by Langelier [14] and entangles and agglomerates the fine particles, and orthokinetic coagulation takes place, resulting in the production of well formed, settleable flocs. Thus, it can be seen that, in the light of these suggested mechanisms, perikinetic or electrokinetic coagulation predominates in the removal of organic color, and orthokinetic coagulation predominates in the removal of turbidity. The suggested mechanism for the electrokinetic phase is consistent with the observation of Langelier that high base-exchange capacity clays, such as the montmorillonites, require more alum for coagulation than do low base-exchange capacity clays and coagulate over a wider range of pH values. It is probably more than a coincidence that, at least for the clays studied by the authors, the pH zone of optimum orthokinetic coagulation with alum, pH 7.5–8.2, includes most of the pH values that have been reported for the isoelectric point of pure aluminum hydroxide.

Packham,[15] in his excellent studies of the alum coagulation of dilute mineral suspensions, which included several clays, found that the suspensions were best coagulated within the pH range 6.8–7.8. Experiments carried out at low pH values showed that none of the minerals studied was coagulated by the maximum dose of 200 ppm alum below pH 5.1. In a later article,[16] the alum coagulation of turbidity from nine

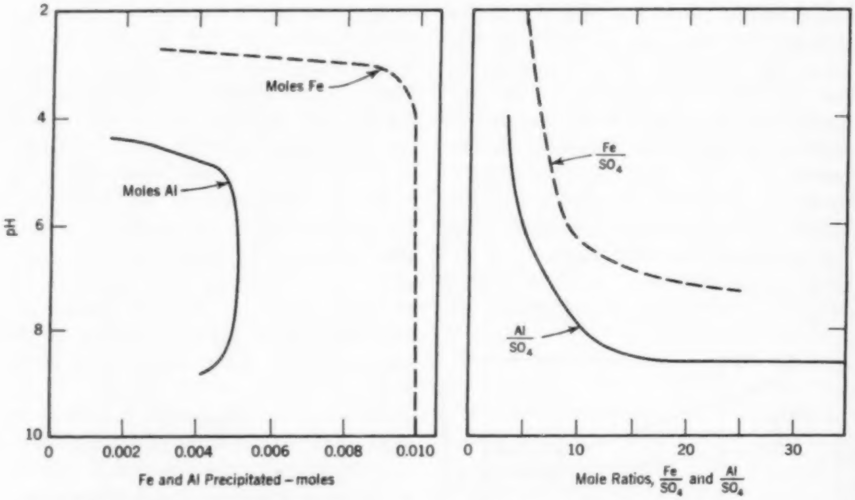

Fig. 15. Effect of pH on Amounts of Iron and Aluminum Precipitated and on Ratios of Iron and Aluminum to Sulfate in Precipitates

The aluminum was precipitated from a 0.005M solution of $Al_2(SO_4)_3$ and the iron from a 0.010M solution of $Fe_2(SO_4)_3$. The substantially different pH ranges within which the two salts are shown to hydrolyze are believed to be the explanation for the differences in the observed behavior of the two coagulants toward colored waters of low alkalinity and buffer capacity (curves from Miller [11]).

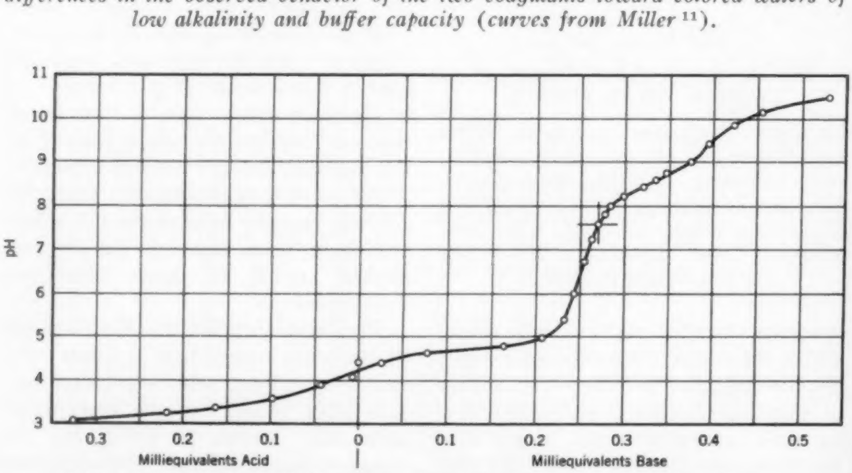

Fig. 16. Potentiometric Titration Curve for Solution Containing Alum

The titration curve is for 300 ml of a solution containing 100 ppm $Al_2(SO_4)_3 \cdot 18H_2O$ (0.27 me) with 0.01N NaOH solution. The first inflection point at about pH 5.4 and the second at about pH 8.2 check well with Miller's curve (Fig. 15, left). The cross mark on the curve at 0.27 me represents the stoichiometric endpoint at which all the alum present is completely hydrolyzed.

English rivers was studied by use of the same techniques. Packham found that these turbid waters behaved in a manner similar to that of the dilute mineral suspensions first studied. He did find, however, as Langelier [14] had previously reported, that montmorillonite, with its high exchange capacity, may be coagulated perikinetically at low pH values. Packham reported his results in terms of an arbitrary value, 0.5 *Dt*, representing the coagulant needed to reduce by one-half the original turbidities of approximately 50 ppm. It is believed that, had the more usual method of plotting alum dosage against final turbidity been followed, his pH range of optimum coagulation would perhaps have been shifted toward somewhat higher pH values than those reported.

That turbidity and organic color behave differently during coagulation probably results from factors involving the relative amounts present, particle size, and charge density. Shapiro [7] was able to recover less than 5 ppm of soluble organic acids from the highly colored water of Lindsley Pond in England, whereas the amounts of turbidity to be removed may be, and usually are, many times greater. With respect to particle size, particles of clay turbidity are usually readily visible under the microscope at a magnification of 250×, whereas the particles of organic color are not visible under the best lighting conditions at magnifications of 1,000×. More specifically, clay particles will usually vary in diameter within the range of 0.1–10 μ, whereas in the authors' studies of Water A, only 5 per cent of the color colloid is retained on a 0.45-μ filter *; 87 per cent of the organic color passes through a filter having a pore size of 10 mμ.

* Millipore filter, made by Millipore Filter Corp., Bedford, Mass.

Conclusions

Microelectrophoresis is proving to be a valuable tool in making it possible to measure the mobility of, and to calculate, where necessary, the zeta potential of, a floc particle at any stage of the coagulation process. Thus, a better understanding has been gained of the complex mechanisms that are involved in coagulation. These studies have confirmed numerous observations of other workers which were not supported by this type of experimental data; at the same time, the studies have shown certain other assumptions to be untenable. For example, Miller's belief, widely accepted for many years, that the trivalence of the aluminum and ferric ions is the predominant factor in coagulation has not been confirmed by the authors' studies. On the contrary, Mattson's assumption that the hydrolysis products of the two ions are most effective in reducing or reversing the zeta potential of floc particles has been confirmed. The behavior of the four clays that have been studied to date confirms Langelier's assumption that base exchange is an important factor in the coagulation of clays, and his concept of the importance of "binder alum" in bringing about orthokinetic coagulation is consistent with all of the authors' data. Further work with other clays and other colored waters is needed and will be forthcoming. In addition, the role played by natural and synthetic polyelectrolytes as aids to coagulation needs further elucidation. But none of the authors' studies to date has served to minimize the importance of the jar test as the most valuable tool for the practical control of the coagulation process.

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High-Accuracy Magnetic Flowmeters

—Douglas R. Lynch—

A paper presented on Sep. 15, 1960, at the New York Section Meeting, Saranac Inn, N.Y., by Douglas R. Lynch, Product Mgr., Fischer & Porter Co., Warminster, Pa.

THE magnetic flowmeter is inherently the most accurate flowmeter yet devised. The primary flow measurement transducer has no moving parts that can wear out, offers no obstruction to the fluid flow, is unaffected by Reynolds number or piping conditions, has a true flow coefficient of unity, and actually meters from infinitesimal motion to the maximum that can be forced through the pipe section. In contrast, one may consider the many decades over which coefficients for variable-head meters have been developed to meet the great varieties of physical and hydraulic conditions that can affect them. Or, in regard to positive-displacement meters, one may consider the different configurations that must be designed to provide longer life and somewhat greater rangeability. Aside from their inherent advantages of operation, practical industrial designs of magnetic flowmeters offer one of the most versatile, trouble-free, and accurate flow-measuring systems on the market.

Historical Aspects

Michael Faraday, the father of the electrical-generator theory, actually conceived the principle of magnetic flowmeters in the early part of the nineteenth century. Faraday attempted to measure the flow rate of the River Thames by utilizing the earth's magnetic field. He put electrodes on either bank of the river and connected them to a special voltmeter that he had developed. Although a futile effort, it was an indication of things to come. There were sporadic reports of related studies from that time to the last decade. Any practical use of the principle, however, was impossible because of the lack of sophisticated electronic equipment to pick out the microscopic signal involved, separate it from the noise and hash in which it was buried, and amplify it so that it could be recorded.

The major development in magnetic flowmeters during the last 15 or 20 years was in the medical field. There was a need for a blood flowmeter that could be inserted in the arteries of the heart. Vincent Cushing is given the credit for this work. In the last decade, the Dutch successfully developed a complete system for industrial service, but only during the past 5 years have several magnetic flowmeters been designed, developed, and marketed in the United States. Today, many thousands of them are in operation in this country.

Applications

Initially, many magnetic meters were installed out of curiosity, or because they were the only possible means of handling a heretofore unmeterable flow.

Now, no longer an oddity, they have been accepted by the paper industry as a standard of flow measurement. Because the meter does not obstruct flow, it eliminates the possibility of stock blockage, dewatering, and process shutdown. Further, because of its capacity of volume measurement, the meter eliminates discrepancies due to changes in stock consistency.

The sewage industry uses a large number of magnetic meters because they need no purging of pressure taps. Also, the installation is more economical, because no long, straight runs of pipe are needed, and the pumping requirements are significantly reduced. The chemical industry utilizes magnetic meters because they can easily handle such tough applications as spin-bath acids, wet-process phosphoric acid, and hydrofluoric acid. The food industry, too, uses the meters for their ability to measure such slurries as tomato stock, goulash, and baby food. Also, the meters can be cleaned in place along with the rest of the process pipeline, and their construction can be entirely sanitary.

The water supply industry today uses a relatively small percentage of the total number of magnetic meters currently installed. The industry certainly considers important the feature of obstructionless flow measurement—fully independent of viscosity, density, and piping configuration—providing extremely wide flow rangeability. Most important, however, is that the accuracy and stability of the magnetic meter are equal to, or better than, those of other types of present-day flowmeters.

Definition of Accuracy

The word *accuracy* is one of the most misused and misunderstood words in the language. It means something different to each engineer, plant operator, consumer, and manufacturer. For the purposes of this article, the ASME definition of accuracy is used:

> Accuracy in measurement is the degree of correctness with which a measuring means yields the true value of a measured quantity. The true value refers to accepted engineering standards, such as a standard centimeter, gram, etc. It is assumed that a true value always exists even though it may be impossible to determine.[1]

Because a measurement device for flow rate is the subject of this article, three concepts of accuracy should be cited: (1) percentage of instantaneous flow rate, (2) percentage of maximum flow rate, and (3) percentage of totalized flow.

The first concept concerns accuracy established as a percentage of the actual operating point or, as it is more commonly called, a percentage of instantaneous flow rate value. For a scale having 100 units, if the accuracy is ±1 per cent of instantaneous rate and the meter is operating at 100 per cent, the limit is ±1 unit. When the meter is operating at 10 per cent, the accuracy is ±0.1 unit.

The second concept of flow rate accuracy is its measurement as a function of full scale. If full scale is 100 units and the accuracy is 1 per cent of full scale, the accuracy over the entire range of measurement is ±1 unit. Therefore, at 10 per cent of scale, the accuracy as a function of instantaneous rate would be ±1 unit out of 10, or ±10 per cent.

The third concept of accuracy is its measurement as a function of totalized flow. For ±1 per cent of totalized

flow, and 100 units, the limit is ±1 unit; for 1 per cent and 1,000 units, the limit is ±10 units.

It is a physical impossibility for every measurement to be always within the limits defined by the statement of accuracy. To cover this aspect, reference is made to an article by Jorissen [2]:

> It thus appears that a figure equal to twice the standard deviation could be considered as sufficiently characteristic of the accuracy of measurement to justify a systematic use of this quantity; it is both scientifically correct and satisfactory to the laymen, since only 5 per cent of the results can be expected to be in error by a larger amount.

Thus, 95 per cent of all the measurements can be expected to fall within the specified limits of accuracy.

Operating Principle

The magnetic flowmeter operates as a simple a-c generator, defined by Faraday, in which the motion of a conductor through a magnetic field induces a voltage within the conductor. Specifically, the magnetic flowmeter is a nonmagnetic pipe, whose inner surface is an excellent electric insulator (Fig. 1). It conveys a conducting liquid at a velocity V (in feet per second) across an electromagnetic field of flux density B (in volt-seconds per square foot). At opposite ends of a pipe of diameter D (in feet), which is normal to the direction of motion of the liquid and the plane of the field, are electrodes through but flush with the pipe wall. These electrodes detect a voltage E_o (flow signal delivered to secondary coil) due to flow. In accordance with Faraday's law, this voltage is equal to:

$$E_o = BVD \qquad (1)$$

Therefore:

$$V = \frac{E_o}{BD} \qquad (2)$$

$$V = \frac{q}{A} \qquad (3)$$

in which q is the volume flow rate, in cubic feet per second; and A, the flow area, in square feet. After substitution of Eq 3 into Eq 2, the result is:

$$q = \frac{E_o A}{BD} \qquad (4)$$

When Eq 4 is multiplied by the area of flow, $A\left(\frac{\pi D^2}{4}\right)$, and the coefficient of flow, K, the result is:

$$q = K\frac{\pi E_o D}{4B} \qquad (5)$$

From Eq 5 it may be seen that the meter gives true or universal volume measurement, because density or a function of density does not enter into the equation. Further, the induced voltage is directly or linearly proportional to flow rate and, as the flow coefficient is unity, there is no characteristic curve, S hook, or even the slightest deviation from a straight line. In summary, the magnetic flowmeter acts as a simple generator: the liquid is the armature, and as the liquid passes through the magnetic field, it develops a voltage that the electrodes pick up just as the brushes of a standard generator do. The faster the liquid moves, the greater the voltage induced. If the output of these electrodes is directed to a standard a-c potentiometer, an indication or record of the rate of flow through the meter is obtained.

The output of the meter is a true weighted-average velocity for practically any flow pattern. The total induced voltage, E_o, is a summation of the effect of each particle as it moves

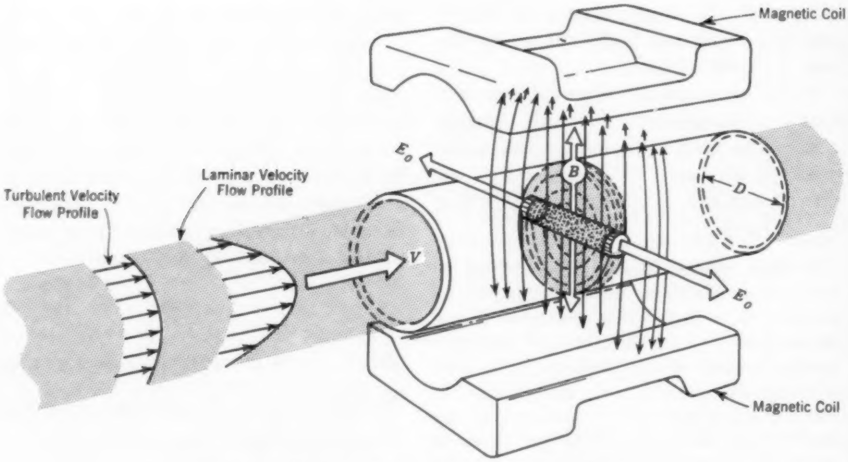

Fig. 1. Operating Principle of Magnetic Meter

The letters represent: V, *flow velocity, in feet per second;* E_o, *voltage;* B, *flux density, in volt-seconds per square foot; and* D, *effective diameter of flowmeter base, in feet.*

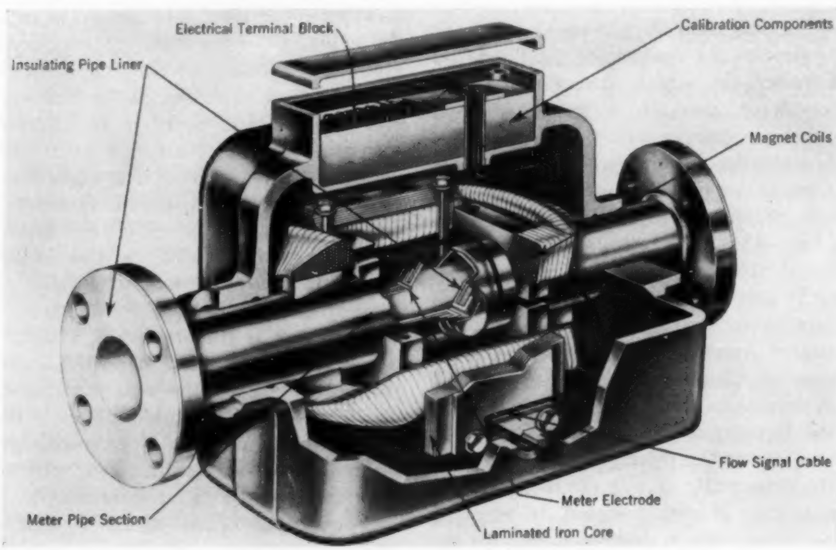

Fig. 2. Cut-Away View of Magnetic Flowmeter

The meter consists of four major parts: (1) pipe section, (2) electrodes, (3) field coils, and (4) calibration components.

through the entire metering area or cross section across the plane of the electrodes. Therefore, the flow coefficient is true unity, provided that an absolutely uniform or parallel field is utilized. When this is considered, and also that density does not enter into the basic equation, it can be seen that the magnetic flowmeter is not affected by the many variables that hamper the operation of conventional flowmeters (Table 1).

Components of Meter

A magnetic flowmeter is made up of four major parts (Fig. 2). First is the pipe section itself. It must be nonmagnetic, and the inner surface must be an excellent electrical insulator. Also, it must be noncorrosive and nonerosive with the liquids it is to carry. Pipe of plastic-lined * stainless steel, neoprene-lined stainless steel, vitreous-enamel-lined stainless steel, or glass fibers † meets the requirements.

The second major part of the meter consists of the electrodes, which run normal to the axis of motion and the plane of the field. These must be nonmagnetic and excellent electrical conductors. The electrodes extend through the pipe wall but are flush with the inner surface of the pipe, so as to provide no obstruction to the liquid.

The third part consists of the field coils and iron that generate and shape a very uniform and parallel magnetic field through the metering section.

The fourth part is a set of calibration components that are included on each primary unit, though they do not enter into the specific function of that unit. Their purpose is, first, to provide the ultimate reference or rebalancing signal to the a-c potentiometer and, second, to insure interchangeability between meters and readouts.

Recording System

The induced voltage, which is proportional to the volume rate of flow through the meter, is carried to a simple a-c potentiometer. There it is compared with a known reference to determine and indicate or record the rate of flow in desired units. The reference, which can be likened to the standard cell or battery in a thermocouple potentiometer, is developed at the same source as the primary element. It is a transformer that is installed in series with the main field coil windings of the primary element. Thus, if anything should affect the flux density and thereby change the induced voltage (even though there is no change in flow rate), the reference value is also changed by a like amount, and the relationship between the two remains absolutely correct. In this way, the flow system is fully independent of power line variations of both voltage and frequency up to ±10 per cent. Further, it is unaffected by changes in ambient temperature or changes in resistance due to aging of wires.

Figure 3 shows the complete magnetic-flowmeter system.‡ The induced voltage of flow signal is compared with the reference or balancing voltage on a pair of balancing transformers. If there is a difference between the two, it means the flow is other than that which is being indi-

* Teflon, made by E. I. du Pont de Nemours & Co., Wilmington, Del.

† Fiberglas, a product of Owens-Corning Fiberglas Co., Toledo, Ohio.

‡ Including Model 10D1416 magnetic flowmeter and Series 1100BC indicator-recorder instrument, made by Fischer & Porter Co., Warminster, Pa.

cated. Through the difference of these two voltages, an error signal is developed and passed on to a high-gain servoamplifier. The output of this amplifier then drives a servomotor to which are connected both the indicating or recording pen and the rebalancing slidewire. The output of the rebalancing slidewire is connected through the range unit back to the rebalancing transformers.

As the slidewire positioner changes, so does the rebalancing voltage, to a point where the flow signal and rebalancing voltages are identical. At that point, the system is in null balance and is indicating at the correct rate of flow.

The range network is uniquely set up, so that at any time any flow value equivalent to 1–30 fps of fluid velocity through the pipe can be set up as full scale of the instrument.

In a practical sense, this means that if a system is established for 100 gpm, and actual operating conditions indicate a need to go to 200 gpm, a simple doubling of the range dial will set up the new capacity. Conversely, if a plant is running at a fraction of its engineered capacity, a lower full-scale value may be dialed in order to obtain the percentage of rate accuracies.

A standard time-pulse integrator may be included within the potentiome-

TABLE 1

Effects of Fluid and Physical Variables on Flowmeters

Variable	Magnetic Flowmeter*	Variable-Area Meter	Variable-Head Meter	Turbine-Type Meter
Viscosity	no effect	viscous drag on float caused meters to be sensitive to changes in viscosity	variations in flow profile due to viscosity causes meters to be sensitive to changes in viscosity	variations in flow profile due to viscosity causes meters to be sensitive to changes in viscosity
Slurries	no effect	effects of consistency vary with type of slurry encountered	effects of consistency vary with type of slurry encountered	not recommended for slurry service
Density	universal volume measurement; unaffected by changes in density	buoyed-float weight a function of fluid density; flow indication varies as square root of the change in density	flow proportional to change in head, of which density is a function; flow indication varies as square root of change in density	universal volume measurement; unaffected by changes in density
Temperature	negligible effect over ordinary temperature range	negligible effect over ordinary temperature range	negligible effect over ordinary temperature range	negligible effect over ordinary temperature range
Pressure	no effect in liquid measurement	no effect in liquid measurement	no effect in liquid measurement	no effect in liquid measurement
Entrained air	measures total quantity of fluid through meter	entrained air reduces effective fluid density, resulting in change in flow indication	entrained air reduces effective fluid density, resulting in change in flow indication	measures total quantity of fluid through meter
Conductivity	requires minimum threshold of conductivity for operation; changes above this level have no effect	no effect	no effect	no effect
Piping configuration	no effect	no effect	flow indication varies widely with up- and downstream piping configuration	affected by upstream piping; meters include built-in flow straightener, eliminating this result

* Made by Fischer & Porter, Warminster, Pa.

ter housing. This electromechanical unit operating from the basic dial spindle converts flow rate per unit of time to total flow. Thus, the magnetic flowmeter can be used for either direct rate measurement or as a totalizing type of flowmeter.

Measurement of Accuracy

Of primary concern to those in the water supply field are the accuracies possible with magnetic flowmeters and the method of checking accuracy in the field. The first consideration is that of the primary-flow transducer.

In order to check the accuracy of the meters, a master standard hydraulic calibrator is necessary. The master hydraulic standard of one meter manufacturer * is a dynamic weighing device, whereby a head of liquid in a standpipe is balanced by a mercury manometer. This is fully described by Shafer and Ruegg [4] of the National Bureau of Standards. It is significant that, as mentioned by Shafer and Ruegg, personnel were unable to state any errors in the industrial system available today merely by virtue of the deviation from the Bureau of Standards' system. Instead, because the algebraic average of all four systems discussed in their article (including that of the National Bureau of Standards') agreed within ±0.06 per cent, it was deemed that the average of all four systems was a base that is closer to absolute perfection than any one of the systems. The algebraic deviation of the manufacturer's hydraulic standard from the accepted base was −0.02 per cent. The point scatter for individual runs about this accepted base was less than ±0.15 per cent.

All magnetic flowmeters 14 in. in size and smaller are checked against the standard to determine their actual meter factor. The meter factor is defined as the hydraulically determined average diameter of the metering section. This diameter is then used to calculate the flow rate in the customer's units from the velocity setting of the range dial in the secondary instrument. The simple equation of flow through a pipe ($Q = VA$) describes the procedure.

Two other factors remain to be determined about each primary flow element: the uniformity of the flux field, and that the ratio of signal to rebalancing voltage is identical for a given velocity in any size meter. The latter is accomplished through the use of a special dry calibrator whose arbitrary scale units were originally determined from a standard magnetic meter, which in turn had been previously certified on the hydraulic calibrator. All future magnetic meters of the manufacturer will be referred to the standard, which remains in the manufacturer's possession. It is periodically recalibrated on the master hydraulic standard and is used to certify the accuracy of the dry calibrator.

Because the output of every magnetic flowmeter is consistent for a given liquid velocity, it is possible to produce secondary readout instruments that are interchangeable with any primary flowmeter. To accomplish this, the input characteristics of each secondary instrument are calibrated to be exactly identical. This is done by producing a special flow simulator or secondary calibrator against which all magnetic flowmeters are checked. This calibrator can be compared to a standard manometer used to certify a differential-pressure readout instrument. It will simulate an exact known flow rate through the secondary readout instrument.

* Fischer & Porter Co.

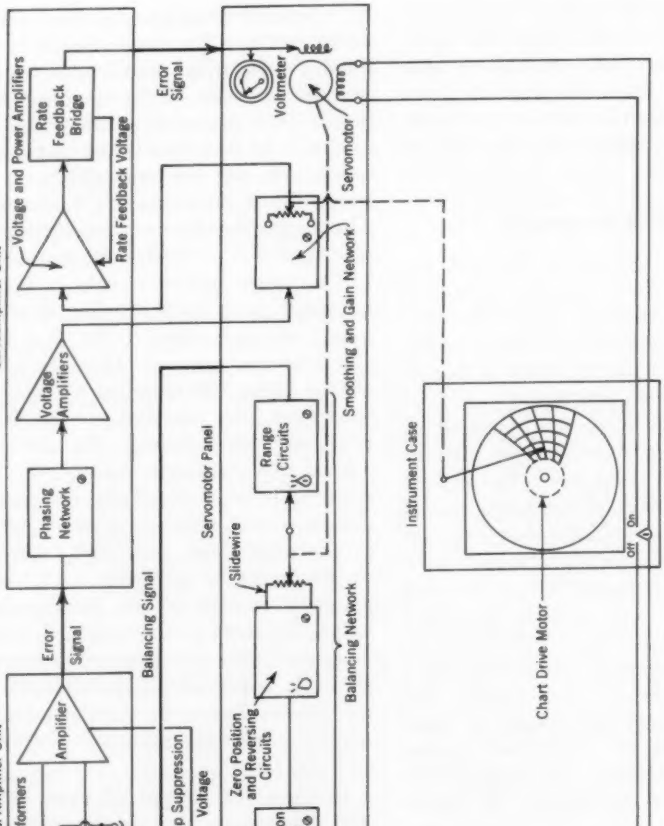

Fig. 3. Magnetic-Flowmeter System

The induced voltage of flow signal is compared with the reference voltage on the balancing transformers. If a difference between the two voltages exists, an error signal is developed and passed on to a servoamplifier.

For example, if the range unit on the secondary readout is set up for full-scale velocity of 10 fps, and the secondary calibrator is set up to simulate 5 fps of liquid velocity, the secondary instrument should read 50 per cent of chart. If the reading of the secondary calibrator is changed to 10 fps, the recorder will show 100 per cent of chart. The secondary calibrator is a precision voltage divider network whose relationships have been checked against a five-place Wheatstone bridge.

Periodic calibrations of both production flowmeters, complete with production secondary instruments, certify the continued maintenance of the original basic standards.

Integration of Flow

Integration of flow is a common requirement for water utility applications. A standard mechanical integrator, mounted within the recorder case, is employed for flow totalization. It contains a spiral cam whose angular position corresponds linearly with the angular position of the potentiometer movement and recorder pan. Accuracy of the integrator, however, is not related to the accuracy of the pen. A stroke arm, mounted on a one-way clutch drive, sweeps a stroke every 2.5 sec. The length of each stroke is limited by the cam position. Thus the registered numbers are stationary during a fraction of each 2.5-sec period; then they suddenly advance on the downstroke.

Eight digits are employed to minimize the duration of calibration tests when accuracy requirements are high. Certification of the integrator is nominally accomplished by connecting the complete readout system to the standard secondary calibrator referred to before. Feeding-in a fixed, known signal for a sufficiently long time to avoid large time errors should produce an integrated total that compares very closely to that calculated from the known time. Many checks are required over the entire scale to insure true linearity in the mechanically cut cam.

Maintenance of Accuracy

When a meter has been certified and proved at the factory, and is installed and operating in the field, how does one know if anything has happened to the meter to affect its original accuracy? The answer to this is another question: How does one know that once installed the accuracy of a differential-pressure producer has not changed? The only absolutely certain way to prove the accuracy is to remove the meter from the line and check it against a master standard. Short of this expensive procedure, one might measure the basic dimensions to insure that the critical metering area has not been eroded or corroded. Also, one could check pressure taps to see that they are open and free, and inspect upstream and downstream piping conditions to see that there are no physical changes that could upset the original calibration.

A standard manometer, used with a differential-pressure measuring instrument, insures continued accuracy of the instrument. A comparable method may be used to insure the accuracy of a magnetic-flowmeter system. When the meter body is installed and full of liquid, the electrodes have a given resistance that can be measured and recorded. The rebalancing voltage, too, can be ascertained. Thereafter, periodic checks of these two values, along with inspection of the pipe itself for mechanical damage or large-scale erosion, certify that its output has

not shifted. Special secondary calibrators or flow simulators are available to the customer for use in checking the accuracy of the secondary indicator, recorder, or integrator.

Obtainable Accuracies

The subject of obtaining high accuracy with a magnetic-flowmetering system has been discussed at length. There remains the question of exactly what the accuracy is. Standard industrial magnetic flowmeters provide flow rate accuracies of ±1 per cent of full scale. Because of the inclusion of a special calibrated-range adjustment, one can manually change full scale to meet different circumstances, so that accuracies of ±1 per cent of the flow rate can be approached. The standard mechanical integrator has an individually rated accuracy of ±0.5 per cent of instantaneous rate. Thus, to obtain the accuracy of integrated value, the percentage of maximum accuracy of a magnetic-meter system, converted to rate, must be added to the accuracy of the integrator.

For example, operated at 50 per cent of full scale, the magnetic-flowmeter accuracy would be ±2 per cent of instantaneous value. Adding to this percentage the accuracy of the integrator gives a total integrated accuracy of ±2.5 per cent, while the meter operates at the given point. If wide fluctuations in a flow are expected, accuracy can be assumed to be only the least obtainable—that is, ±1.5 per cent of full scale.

Special magnetic-flowmeter systems have been devised to provide an accuracy of a percentage of rate rather than a percentage of maximum accuracy. In such meters, the readout instrument is modified to utilize high-accuracy and linearity components and direct fixed linkages from the servomotor to the integrator. A number of mechanical modifications and improvements are also made to the integrator. This system is then calibrated as a complete entity in the hydraulics laboratory. Thereafter, the integrator is certified in a manner similar to that discussed previously.

Some systems have been developed to provide a total integrated accuracy of ±1 per cent of instantaneous values over flow range ratios as high as 20:1 fps. This represents a significant improvement. To certify and guarantee that accuracies such as these do exist in the meter, however, is a very expensive, tedious, and time-consuming project.

Still needed is a readily available, standard secondary instrument whose accuracy, linearity, ability, and life expectancy are equivalent to those of the primary flow transducer. This is now being developed, so that in the near future, magnetic systems will be available for accuracies of ±0.5 per cent of instantaneous rate over a 20:1-fps range at any given full scale setting.

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Future Demands on the Water Supply Industry

Frank C. Mirgain and Marvin T. Skodje

A paper presented on Sep. 23, 1960, at the North Central Section Meeting, St. Paul, Minn., by Frank C. Mirgain, Dean, School of Eng., and Marvin T. Skodje, Prof. of Civ. Eng., both of North Dakota State Univ., Fargo, N.D.

THE first thoughts that occur to those in the field of water supply when they consider future demands on their industry is the very rapid increase in world population and the continuing increases in per capita water consumption. It is estimated that the present rate of water usage in the United States is 300 bgd and that, by the year 1980, daily usage will total 500–600 bgd.

Municipal water supply usage has, in the span of only a few years, increased from a per capita rate of 100 gpd to 140 gpd. By 1980, this usage will reach 175–200 gpd. Regardless of the source that may be quoted, it is obvious that the demands on the nation's water resources and supply facilities are increasing at a tremendous pace. In depicting present and future demands on water resources, figures on the rate of water usage can be compared to the annual rainfall, which, in the United States, amounts to 1.5 quadrillion gallons. Nearly one-third of this amount constitutes runoff and is available as surface water or contributes to ground water recharge. It is estimated that the total storage provided in usable ground water reservoirs in the United States is approximately 10 years of annual precipitation. From these estimates, the total abundance of fresh water becomes apparent. Notwithstanding, however, localized and regional shortages of water do exist as a result of uneven seasonal and geographic distribution of rainfall and, in some instances, as a result of a lack of imaginative or farsighted planning. Although the use and availability of water are important aspects of future demands on AWWA, they actually represent only one small facet of the overall picture.

AWWA Objectives

In portraying the future demands on the water industry and AWWA in their proper perspective, one can begin by considering the objectives of the Association as set forth in its constitution:

The objects of this Association shall be:

a. To advance the knowledge of the design, construction, operation, and management of water utilities

b. To consider and deal with the problems involved in the production and distribution of safe and adequate water supplies

c. To promote satisfactory relationships with the consuming public

d. To give proper consideration to and express opinions upon practices which will enable the industry to render the best possible service to the public

e. To do whatever things are necessary and proper for the accomplishment of the objectives herein set forth, all of which

shall be consistent with the public interest and with the interests of the public water supply field.

These objectives, written into the constitution by the founders of AWWA, have been, and still remain, the broad responsibilities and demands of the future. At the present time, however, there is a greater knowledge and comprehension of the tasks confronting the industry than there was when the Association was in its infancy. Because of the tremendous scientific and technologic advances in the United States, not only have the hazards to the nation's water resources become more numerous and complex, but also the potential of the water supply profession for service to society has been greatly expanded. The problem of chemical pollutants a decade ago, for example, was minor in comparison to that which exists today.

Problems and Related Studies

The earliest recorded water treatment methods required to produce safe, potable water were sedimentation, with exposure to sunlight, and detention. Much later, slow sand filtration was found to render grossly contaminated water safe for consumption. Early contamination factors of which men were aware consisted primarily of turbidity and fecal organisms of unknown character.

Through experimentation and study, the nature of waterborne contaminants and their physiologic effects came to be understood. Through research in medicine, bacteriology, virology, chemistry, and related sciences, a greater awareness developed of the multitude of toxic and pathogenic agents that may be introduced into, and may be transported by, water. The awareness of these potential hazards requires workers in the field to study diligently the methods by which these agents may be detected, neutralized, or destroyed. Then safeguards to prevent their entrance into water supplies must be promoted.

In addition to the elements that constitute a potential physiologic hazard, others exist that are considered objectionable only from the viewpoint of aesthetics, or because they adversely affect industrial processes, or, perhaps, because they affect palatability of water. As living standards are elevated, consumer demands for water quality are also raised. The presence of iron, manganese, calcium, magnesium, sulfates, and other inorganic and organic substances that produce tastes, odors, hardness, turbidity, or color is considered increasingly objectionable. The instability of some waters produces adverse reactions on distribution systems, plumbing fixtures, and mechanical equipment. Attention must also be directed to the effects of corrosion and tuberculation.

A gigantic problem facing the nation and the world is the conservation of water resources. Equalization of runoff, control of evaporation, inducement of percolation for ground water recharge, waste water reuse, and water rights legislation are areas that must be continually explored.

How should the water supply profession approach its problems? The first logical step is the promotion of greater research activity. Each problem can be explored by eminent men from the profession, provided that funds are available. One of the greatest contributions of AWWA can be the promotion of funds from governmental sources and industry. The Association must continue to support agencies presently involved in research.

The US Army Corps of Engineers, USGS, USPHS, and the Bureau of Reclamation, as well as agencies of the states, counties, and cities, are all working on water resource development and conservation. In the area of salt-water conversion, the federal government has provided $10,000,000 for the establishment of five experimental demonstration plants in the United States incorporating five methods of salt-water conversion which show promise of an economic breakthrough.

In addition to government-financed research in salt-water conversion, Southern California Edison Co. has given Cleaver-Brooks Co. a contract for the construction of a 100,000-gpd experimental evaporation unit at Edison's new steam plant at Oxnard, Calif. Ionics Inc. has installed the first commercial conversion plant east of the Mississippi River for the New York State Thruway Authority. The plant is a 12,000-gpd permselective membrane unit installed to serve a thruway restaurant.

The National Institutes of Health continues to support many research projects such as the study of the toxicity and solubility of cadmium and chromium, which was begun in 1954 at Michigan State University; the study of protective coatings for corrosion protection, also at Michigan State University; research into coagulation, which began in 1957 at the University of Florida; and the study of impurities in liquid chlorine, started at Purdue University in 1958. Possibilities for continued research studies are unlimited in such areas as control of evaporation; ground water recharge; coagulant aids; disinfection techniques; ultrasonics; effectiveness of chlorine residual; prophylaxis; sedimentation; corrosion control; distribution systems; industrial chemical contaminants; virology; nematodes; fungi; algae; automation; detection and destruction of biologic, chemical, and radiologic warfare agents; plumbing systems and fixtures—an almost endless list.

Corrosion effects are estimated to cause a loss of five to six billion dollars annually in the United States. The reduction of this annual expense alone would obviously be a financially worthwhile research effort. Other research studies will produce results that cannot be measured monetarily. The results of fluoridation have been dramatic. Research has shown that the addition of ordinary phosphates also aids in dental protection. Although phosphatation is not intended for water supplies, the advantage of water for prophylaxis can easily be seen.

The use of recharge of ground water sources as a means for water storage is hampered by such factors as health hazards, chemical and biologic clogging of aquifers, the diffusion of air into the aquifer, and adverse effects of temperature on ground water. As localized shortages of water increase, the equitable usage of available water becomes of paramount importance. Under the riparian doctrine, all persons owning land were entitled to the use of water flowing by in its natural channel, undiminished in quantity and unimpaired in quality. Modern legal interpretations now take a more realistic cognizance of the rights of reasonable usage. Consultation with legislators to provide assistance in the drafting of legal machinery to protect the water rights of individuals and communities becomes part of the responsibility of water supply personnel.

Another broad field of study closely related to the question of water rights

is the problem of assessment for water utilities and the charges for water consumed. The numerous elements involved in the operation costs of water utilities are exceeded by the number of methods and combinations of methods for assessment of these costs. To provide an equitable system of cost assessments that could be adopted uniformly throughout the industry is a creditable goal in itself.

The revision and expansion of water treatment methods and standards; standards of water quality and chemical purity; and standards for tanks, mains, well casings, joints, and coatings are all areas of study and effort that will require the combined dedicated efforts of all AWWA members. The use of advanced electronic equipment in the water supply industry has opened new horizons in plant and distribution system design and operation. The advance toward automation in plant operations has shown great promise where applied, although there is a long way to go before all plants, large and small, make the fullest use of electronic controls. The use of electronic network analyzers for the analysis of distribution systems is on a limited basis, because of the investment cost for analyzers and the training required for competent operators.

Conclusions

Through the US Army Corps of Engineers' and the Bureau of Reclamation's mammoth job of controlling runoff and constructing water storage facilities, supplemented by the work of USGS in the investigation of ground water sources, progress is being made toward a more effective use of the nation's water resources. In this respect, the assistance rendered by water conservation and water pollution control agencies is also recognized. The results of experiments in the field of induced precipitation indicate a need for continued research and experimentation. The advancement of research, then, appears to hold the key to the solution of problems facing water supply men if they are to meet the future demands placed on the Association and the profession.

The enumeration and elaboration of all of the water supply industry's future responsibilities and goals are too lengthy for inclusion here. The future demands on the industry and its response to these demands are limited only by the boundaries of man's own imagination and purpose.

Taxation of Water Rights in California

C. Marvin Brewer

A paper presented on Oct. 26, 1960, at the California Section Meeting, Long Beach, Calif., by C. Marvin Brewer, Pres., California Mutual Water Companies Assn., Corona, Calif.

PEOPLE have always hated to pay taxes, especially when they thought the taxes were unfair. Although most citizens recognize the necessity for taxes, they actively oppose being taxed without representation and equalization.

Accordingly, many water-producing and distributing entities in California denounce the taxation of water rights by certain counties because the taxes are often unequal and are levied against some unrepresented taxpayers. These entities supply domestic, municipal, irrigation, and industrial water to most of the consumers in the state.

Location of Sources

In California, with its high mountains and great valleys, with its extremes of temperature and precipitation, most of the water is consumed in the areas where an insignificant amount can be produced locally. Most of the farms, as well as the centers of population, are located in semiarid valleys and consume water that is produced and stored in the mountain areas. This situation necessitates the transportation of water through great aqueducts 200–300 mi long from the areas of surplus to the areas of need.

New Tax Concept

Owners of works to divert and transport water from areas of surplus to areas of need have paid taxes on property outside their boundaries. Significantly, private owners have paid taxes on their land and on all improvements, whereas public owners have paid taxes only on the land.

Only recently, the mountain counties, or counties of surplus, became aware of the fact that the rights of entities to take these waters were intrinsic property rights and a potential source of vast new revenue. California courts have approved the taxation of water rights.

What appealed to these counties was the ideal position of being able to levy and compound these taxes, based on various formulas, against nonresident, nonvoting property owners.

Valuation Methods

Because there is virtually no market for water rights, and because the rights themselves were acquired by the entities by virtue of beneficial use, not generally by the payment of any sum of money, the approach to valuation has been as varied as the counties making the assessment. For example, the approach taken by Inyo County is one in which assessment was made on the value of the water when delivered 360 mi to the city of Los Angeles. This assessment for 1959–60 alone was $19,750,000, which, with a 25 per cent

assessment factor, would indicate a market value of $79,000,000.

Methods for San Francisco

Water rights owned by San Francisco are currently assessed in the counties of Alameda and Tuolumne. For each assessment, however, an agreement on amounts of assessed value for the current year (1959–60) has precluded both valuations from going to a final determination.

The two major methods of assessment are described below.

1. *Capitalization of actual net revenue* (no substitutional costs or sales prices considered). From the utility's income all costs and expenses are deducted. The remaining net revenue is capitalized. The result is said to constitute full cash value of the water rights.

Because more than one source of water was involved in San Francisco, the assessor allocated revenue and costs to the taxing county on the basis of the percentage of water produced in the county to total production of water. The assessor also used a 5 per cent capitalization rate.

Capitalization of actual net revenue is second in simplicity only to the historical-cost approach to value, but it will not produce a result where there is no net revenue. As San Francisco operates its water and power facilities on an annual cash basis, this method leads to a discussion of what the proper deductions from gross revenue are—depreciation, ad valorem taxes, and interest on indebtedness. In other words, value depends upon the existence or nonexistence of costs and the taxing agency's right to disallow these costs.

The assignment of capitalized net remaining revenue solely to water rights, rather than to the entire entity to be apportioned, also appears to be a major objection to this method.

2. *Substitutional sales price and actual costs incurred.* This method merely substitutes the unit price that would be charged by a comparable seller in the general area served by San Francisco for the actual sales price charged by the utility being taxed. The capitalization method is then employed to derive a full cash value.

San Bernardino County Method

In San Bernardino County, the assessor has fixed a value for the water rights of certain mutuals (and the city of Riverside) exporting water from the county. The method of fixing value is based on a substitute supply. The costs of producing the existing supply have been compared with the estimated costs of a substitute supply, and the difference has been capitalized to give a value to the water right.

The assessor first determined the quantity of water exported and subject to taxation. These figures were based on averages computed from 1952 to 1956, and were obtained from information on file with the state water rights board.

Next, annual production costs were determined on the basis of certain assumed costs. These costs had to be less than those of the substitute supply in order to make the formula work. For that reason the conveying facilities for the water were frequently disregarded or shortened to reduce the costs. This was done by assuming that there was a market for exported water within the county (for example, the city of San Bernardino) and determining the length of the conveyance system by the distance to this assumed market. The longest transmission con-

veyance allowed in any computation was only 7,000 ft.

The last step was to determine the costs of a substitute supply. These figures were obtained by assuming the costs to the taxing company or entity of producing a substitute supply in the area where the water is delivered. The availability of such a supply was not considered, nor was the possibility of obtaining a cheaper supply from gravity flow. Again, substitute supply costs were assumed; actual figures were not used.

The difference between the computed cost of production and the computed cost of the substitute supply was capitalized at 7.5 per cent. For a gravity supply, higher capitalization figures were used, which in one instance reached 13 per cent.

In one computation for one of the exporters, the assessor determined that the cost of producing an existing supply in the county of San Bernardino was $2.43 per acre-foot. He computed the cost of a substitute supply to the same utility at $3.94 per acre-foot. The net difference, $1.51 per acre-foot, was capitalized at 7.5 per cent and the resulting figure was reduced to 25 per cent to determine the water right valuation placed on the assessment roll.

Equalization Abuses

The effect which taxation of water rights has had on farmers is significant. For example, before the turn of the century farmers in Riverside and San Bernardino counties were encouraged to transport water from a swampy area in San Bernardino County so that the land might be reclaimed. Lacking the resources, as individuals, to build the necessary canals and pipelines, they joined together to form mutual nonprofit water utilities. Some of these mutuals serve in San Bernardino County and others serve in Riverside County.

Under a complicated and little understood formula, the tax assessor proceeded to levy assessments against mutuals both within and outside the county. There followed the usual appeal to the board of supervisors, sitting as a board of equalization, with the result that the assessment on San Bernardino County mutuals was equalized to zero and the assessment on Riverside County mutuals was allowed to stand. Members of the Riverside County mutuals had no part in the election of the board. The frustration of their attempt at equalization is obvious.

It cannot be too strongly emphasized that, without equalization, water rights taxation can be increased and compounded until confiscation results. In the Nov. 13, 1959, issue of the San Bernardino *Sun,* Nancy Smith, a member of the county board of equalization, stated: "It has always been my hope that, by taxing this water which Riverside is taking from our basin, the companies involved would be encouraged to use Metropolitan Water District water and leave ours here."

Hydroelectric Generation

An option is frequently available in planning for electric-power generation in California. With hydro generation, the primary elements of capital cost are the creation of water storage, the generator plant, and the transmission to point of distribution. The costs of water storage and power transmission can be eliminated by using steam-driven generators near the area of use.

The decision to elect hydro generation, with its greater capital cost, is made after analysis of relative opera-

tional cost data. The fact that water rights taxes will be added to hydro operational costs may be the factor that tips the scale in favor of steam generation. Thus, water rights taxation results in a waste of water that might be used without being consumed while raising the consumption of oil, thus dissipating another natural resource.

Water Rights Taxation Conference

Alarmed by the inequities in water rights taxes, a group representing municipalities, water districts, mutuals, public utilities, irrigation districts, leagues, and farmer organizations formed and adopted the name "Water Rights Taxation Conference." Meetings were held in San Francisco and Los Angeles. The general sense of the proceedings was that a constitutional prohibition against taxing water rights must evolve, because a formula for equitable assessment could not be found.

Although not unanimously, the conference resolved to propose an amendment, and it is anticipated that it will be presented to the legislature during the 1961 session. The amendment reads:

> Any county, city and county, municipal corporation, public corporation, public district or other public agency constructing or operating a water resource development project wholly or partially outside its boundaries may, in the discretion of its governing body and to the extent and for the periods determined by it, make payments to local tax entities within whose boundaries such project or part thereof is located to assist such entities in providing governmental services or facilities necessitated by such construction or operation. Furthermore, the state may make payments or loans to local tax entities to assist such entities in providing governmental services and facilities where water resource construction projects financed, in whole or in part, by the state, or by the state jointly with the federal government, create an undue burden on the ability of such entities to provide such services and facilities.

The second part of this constitutional amendment has to do with the water rights themselves:

> Except insofar as water or water rights may be taken into account in the assessment of lands upon which water is put to beneficial use, all right to water or to the use of or flow of water in or from any natural stream or watercourse or in or from any ground water source as may belong to this state, or to any county, city and county, municipal corporation, public corporation, public district, public agency, public utility or mutual water company shall be exempt from taxation.

In-Lieu Taxes

The provision for payment of in-lieu taxes evolved because public entities, as distinguished from private entities, are exempt from taxes on their improvements to real property and are thus constitutionally prohibited from paying, in some instances, their fair share of the tax burden.

Although the conference did not propose that the in-lieu provisions be mandatory, the legislature may do so. A representative of one of the mountain counties has suggested that if the first sentence of the proposed amendment were to read "*shall* make payment," and further stipulated that the state board of equalization be empowered to assess and administer and adjust the in-lieu tax as the needs of the areas of origin dictate, there would be no more problem.

Under the proposed constitutional amendment, the counties of origin could be given financial support from

water exporters, in keeping with the essential services those counties provide. The amendment also would curb the natural tendency to levy exorbitant taxes on water producers who have no voice in the election of county officials. The essential premise of the amendment is that, in matters of taxation, there can be no equalization without representation.

Litigation Upholding Water Rights Taxation

The following is a summary of California cases approving the taxation of water rights and explaining the reasons for approving or disapproving the methods of taxation.

The basis for taxation is found in *City and County of San Francisco* v. *County of Alameda.*[1] The water right that was held to be taxable in this case was a right, as against the owners of riparian land in the taxing county, to use water from the stream to which their land was riparian. In other words, the riparian owners had been divested of the privilege of exercising their riparian rights and, while these rights might not be transferred to a nonriparian for use elsewhere, this circumstance did prevent the riparians themselves from using the water, thus making available surplus water for appropriation by the city and county of San Francisco.

In holding that even such a right was taxable, the court pointed out that land stripped of its right to use water frequently became valueless, and hence was of little value for taxing purposes. It explained the reason for making such rights taxable by declaring that an ability to tax such rights was the basis for survival of certain small counties whose natural resources could otherwise be exploited by others who took those resources away. This reasoning continues to be the basis for taxation of water rights.

Waterford Irrigation District v. *County of Stanislaus*[2] extended the principle of the *San Francisco* case by holding that an appropriative right also was "land" within the meaning of Article XIII, Section 1 of the California Constitution and therefore was taxable. It also held that there can be no double taxation unless taxes are imposed in the same year by the same agency for the same purpose upon the same property owned by the same person.

This case again explains the reason for the rule permitting the taxation of water rights as a species of real property.

Alpaugh Irrigation District v. *County of Kern*[3] upheld the right of the County of Kern to tax the appropriative and prescriptive water rights of a district which was exporting its waters to a neighboring county. The court held that the water rights being taxed were a species of real property and that a tax based upon 18,000 acre-ft of water was supported by a stipulated judgment under which the taxed entity was given the right to pump that much water. The court approvel a formula under which the net value of water (recognized sales price in the area minus the cost of production) was capitalized by a factor of 11.53. The sum of $3.50 per acre-foot (sales price) minus $2.87 per acre-foot (cost of production, including power, repairs, lubricants, rentals, plant attendance, depreciation, and taxes) yielded $0.63. Then, 18,000 acre-ft times $0.63 times 11.53 yielded $130,750. Finally, 50 per cent thereof was approved as the assessed value of the water rights.

It was declared to be not material that another exporter was not assessed on its rights. Furthermore, it was not ownership of land that was the basis for taxation; rather, appropriative and prescriptive rights were held separately assessable and taxable.

City of Los Angeles v. *County of Inyo.*[4] The Inyo County assessor levied an assessment on three lots in the town of Independence in which the city of Los Angeles retained water rights. The assessor apparently fixed a valuation on the water rights on these three lots that, coupled with the assessed value of the lots without water, was from 2½ to 3 times the assessment on comparable lots that included the fee and water right. Apparently the value was arrived at by adding the assessment that the assessor believed had been overlooked from 1932 to 1955, but the proper procedure for "escaped assessments" was not followed.

The trial court held the assessment valid, but the appellate court found that the method followed by the assessor was incorrect and resulted in an excessive assessment of the city's water rights. All water rights in the town of Independence were not assessed uniformly. These assessments were in the court's opinion discriminatory, excessive, and invalid.

References

1. *City and County of San Francisco* v. *County of Alameda,* 5 Calif. 2nd 243 (1936).
2. *Waterford Irrigation District* v. *County of Stanislaus,* 102 Calif. App. 2d 839 (1951).
3. *Alpaugh Irrigation District* v. *County of Kern,* 113 Calif. App. 2d 286 (1952).
4. *City of Los Angeles* v. *County of Inyo,* 167 Calif. App. 2d 736 (1959).

AWWA B406-61T

American Water Works Association

TENTATIVE AWWA STANDARD *for* FERRIC SULFATE

This "Standard for Ferric Sulfate" is based on the best known experience and is intended for use under normal conditions. It is not designed for unqualified use under all conditions, and the advisability of use of the material herein described in any water treatment plant must be subjected to review by the chemist or engineer responsible for operations in the locality concerned.

Approved as "Tentative" Jan. 23, 1961

- **Price of reprint—20¢ per copy**
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Table of Contents

This "Standard for Ferric Sulfate" was prepared under the direction of Elwood L. Bean for the Water Purification Division, AWWA. The standard was approved by the Executive Committee of the Water Purification Division and by the Committee on Standardization, and received the approval of the Association's Board of Directors on Jan. 23, 1961.

AWWA B406-61T

Tentative AWWA Standard for

Ferric Sulfate

Part A–Material

Sec. 1A—Scope

This standard covers ferric sulfate for use in the treatment of municipal and industrial water supplies. It is intended for use in connection with Part B (Sampling, Inspection, Packing, and Marking) and Part C (Testing Methods) of this document.

Sec. 2A—Definition

The chemical formula of ferric sulfate covered in this standard is $Fe_2(SO_4)_3$. Commercial ferric sulfate contains variable amounts of water of crystallization and, in the granular form, is either a grayish white or a reddish gray in color. It is prepared by oxidation of ferrous sulfate or by dissolving ferric oxide in sulfuric acid. When in solution, it forms a reddish brown liquid.

Sec. 3A—Information to Be Supplied by Purchaser

In placing orders for ferric sulfate to be supplied under this standard, the purchaser should specify the following details:

3A.1. Standard used—that is, AWWA B406 of the latest revision

3A.2. Affidavit of compliance (Sec. 11A), if required

3A.3. Quantity of ferric sulfate required and method of packing and shipping (Sec. 3B.1)

3A.4. Whether bulk shipments of ferric sulfate are to be accompanied by weight certificates of certified weighers.

Sec. 4A—Caution

Ferric sulfate is mildly hygroscopic and should, therefore, be stored in a dry place. In the feeding of ferric sulfate the correct water ratio (quantity of water to weight of material in the dissolving tank) should be maintained. The manufacturer's directions for feeding should be adhered to.

Sec. 5A—Sampling

Sampling shall be conducted in accordance with Part B (Sampling, Inspection, Packing, and Marking) of this document.

Sec. 6A—Methods of Testing

The laboratory examination shall be carried on in accordance with Part C (Testing Methods) of this document.

Sec. 7A—Impurities

The ferric sulfate supplied under this standard shall contain no soluble mineral or organic substances in quantities

capable of producing deleterious or injurious effects on the health of those consuming water which has been treated properly with the ferric sulfate.

Sec. 8A—Rejection

8A.1. Notice of dissatisfaction with a shipment based on this standard must be in the hands of the consignor within 10 days after the receipt of the shipment at the point of destination. If the consignor desires a retest he shall notify the consignee within 5 days of notice of the complaint. Upon the receipt of the request for a retest the consignee shall forward to the consignor one of the sealed samples (Part B, Sec. 2B). In the event that the results obtained by the consignor's retest do not agree with the results obtained by the consignee, the other sealed sample shall be forwarded, unopened, for analysis to a referee laboratory agreed upon by both parties. The results of the referee analysis shall be accepted as final. The cost of the referee analysis shall be paid by the consignor if the referee analysis shows that the material does not meet this standard and by the consignee if it does meet this standard.

8A.2. If the material is rejected on the basis of the retest or the referee test, the consignor may remove the material from the premises of the consignee, or a price adjustment may be agreed upon by the consignor and consignee.

Sec. 9A—Physical Requirements

9A.1. The ferric sulfate supplied under this standard shall be fairly uniform in size. Not less than 95 per cent shall pass a 4-mesh screen, and 100 per cent shall pass a 3-mesh screen.

9A.2. The material shall be dry, clean, and free from lumps or extraneous materials. It shall be "free flowing" and suitable for storage, without caking, in closed hopper bins and for feeding by dry-feed machines.

Sec. 10A—Chemical Requirements

10A.1. *Ferric iron.* The material shall contain not less than 18.0 per cent water-soluble ferric iron (Fe^{3+}) (Part C, Sec. 6C).

10A.2. *Ferrous iron.* The water-soluble ferrous iron (Fe^{++}) shall not exceed 3.0 per cent (Part C, Sec. 5C).

10A.3. *Insoluble matter.* Not more than 6.0 per cent of the material shall be insoluble in water (Part C, Sec. 4C).

10A.4. *Free acid.* The material shall contain free acid, but it shall not exceed 4.0 per cent as H_2SO_4 (Part C, Sec. 7C).

Sec. 11A—Affidavit of Compliance

The purchaser may require an affidavit from the manufacturer or vendor that the ferric sulfate furnished under the purchaser's order complies with all applicable requirements of this standard.

Part B—Sampling, Inspection, Packing, and Marking

Sec. 1B—Scope

These procedures for sampling, inspection, packing, weighing and marking of ferric sulfate are intended for use in connection with Part A (Material) and Part C (Testing Methods) of this document.

Sec. 2B—Sampling

2B.1. Samples shall be taken at the point of destination.

2B.2. If the ferric sulfate is handled by conveyor or elevator, a mechanical arrangement for sampling may be used.

2B.3. If the material is packaged, 5 per cent of the packages shall be sampled, provided, however, that no fewer than five packages and no more than twenty packages shall be sampled from any one shipment. No sample shall be taken from a broken package.

2B.4. Ferric sulfate may be sampled by the use of a sampling tube that is at least ¾ in. in diameter.

2B.5. The gross sample, which shall weigh at least 10 lb, shall be mixed thoroughly and divided to provide three 1-lb samples. The 1-lb samples shall be sealed airtight in moistureproof glass containers. Each sample container shall be labeled to identify it and the label shall be signed by the sampler.

Sec. 3B—Packing and Shipping

3B.1. Ferric sulfate shall be shipped by one of the following means, as specified by the purchaser: (1) in bulk in trucks or freight cars specially designed for this purpose; (2) in 100- or 200-lb moistureproof multiwall paper bags; (3) in 200-lb moistureproof textile or burlap bags; or (4) in moistureproof barrels or drums containing approximately 400 lb each.

3B.2. The net weight of the packages shall not deviate from the recorded weight by more than 1.5 per cent. If a dispute arises concerning the weight of the material received, judgment shall be based on the certified unit weight of not less than 10 per cent of the packages shipped, selected at random from the shipment.

3B.3. The purchaser may require that bulk shipments be accompanied by weight certificates of certified weighers, or the weights may be checked by the consignee at delivery. Payment shall be based only on the weight of material received.

Sec. 4B—Marking

Each shipment of material shall carry with it some means of identification. Each package shall be marked legibly with the name of the manufacturer and brand name, if any.

Part C—Testing Methods

Sec. 1C—Scope

These methods for the examination of ferric sulfate are intended for use in connection with Part A (Material) and Part B (Sampling, Inspection, Packing, and Marking) of this document.

Sec. 2C—Sampling

2C.1. Sampling shall be conducted in accordance with Part B (Sampling, Inspection, Packing, and Marking) of this document.

2C.2. The sample delivered to the laboratory shall be quartered to approximately 100 g. After thorough mixing, the quartered sample shall be stored in an airtight glass container and weighed out rapidly to avoid change in moisture content.

2C.3. Laboratory examination of the sample shall be completed within 5 days after receipt of the shipment.

2C.4. *Preparation of sample.* Approximately 50 g of the ferric sulfate sample shall be ground to such size that all of it passes through an 80-mesh screen. The ground sample shall then be placed in a tightly closed bottle or jar until analysis.

2C.5. *Disposal.* Samples shall be stored for at least 30 days from date of receipt before disposal.

Sec. 3C—Moisture

3C.1. *Procedure.* Weigh out 10 g (to the nearest milligram) of the ground sample in a tared porcelain dish. Dry for 5 hr in an oven at 110°C. Allow the sample to cool in a desiccator and weigh again.

3C.2—*Calculation:*

$$\frac{\text{Loss in weight} \times 100}{\text{Weight of sample}} = \text{per cent moisture}$$

Sec. 4C—Insoluble Matter

4C.1. *Procedure.* Weigh out 10 g (to the nearest milligram) of the ground sample and transfer into a 250-ml beaker. Add 100 ml boiling water and stir for 30 min. *Do not boil.* Prepare a filter by pressing a 12.5-cm filter paper (Whatman No. 42, or equivalent) into an 8.5-cm Buchner funnel with a 400-ml beaker. Filter the liquid and wash the residue with four successive 20-ml portions of boiling water. Transfer the contents of the filter flask quantitatively to a 500-ml volumetric flask and make up to volume. Save this filtrate for other analyses. Ignite the filter paper and residue in a tared platinum crucible in a muffle furnace. Cool in a desiccator and weigh again. Report results as per cent insoluble matter on an oven-dry basis, using the per cent moisture from Sec. 3C and the formula in Sec. 4C.2, below.

4C.2—*Calculation:*

$$\frac{\text{Wt of residue} \times 10{,}000}{10.0\text{ g} \times (100 - \%\text{ moisture})} = \%\text{ insoluble matter}$$

Sec. 5C—Soluble Ferrous Iron

5C.1.—*Reagents:*

(a) $0.01N$ ceric sulfate. To prepare, add slowly, with stirring, 30 ml concentrated sulfuric acid (H_2SO_4) to 500 ml water; dissolve 5.28 g ceric sulfate [$Ce(H_2SO_4)_4$] in this acid solution and dilute to 1 liter.

(b) Orthophenanthroline indicator solution, prepared by dissolving 0.5 g orthophenanthroline in 50 ml ethyl alcohol and diluting to 100 ml.

(c) 50 per cent hydrochloric acid, prepared by mixing equal parts of concentrated hydrochloric acid and distilled water.

5C.2—*Procedure.* To 10-ml aliquot of the filtrate from Sec. 4C.1 plus 80 ml distilled water, add 5 ml hydrochloric acid. Titrate with $0.01N$ ceric sulfate, using orthophenanthroline indicator (use a 10-ml microburet). Run a blank on 50 ml of water using the same amount of indicator solution. Report results as per cent water-soluble ferrous iron on an oven-dry basis, using the per cent moisture from Sec. 3C and the formula in Sec. 5C.3, below.

5C.3—*Calculation:*

$$\frac{(\text{ml ceric sulfate} - \text{blank}) \times N \text{ ceric sulfate} \times 27{,}925}{\text{Wt of sample (g)} \times (100 - \%\text{ moisture})} = \%\text{ water-soluble ferrous iron } (Fe^{++})$$

Sec. 6C—Soluble Ferric Iron

6C.1.—*Reagents:*

(a) Concentrated hydrochloric acid

(b) Potassium iodide crystals, reagent grade

(c) $0.1N$ sodium thiosulfate (standardized)

(d) Starch solution (0.5 g in 100 ml distilled water).

6C.2. *Procedure.* To a 50-ml aliquot of the filtrate from Sec. 4C.1, add 12 ml concentrated hydrochloric acid in an iodine flask. Add 2–3 g potassium iodide crystals. Seal the glass stopper with water and allow to stand for 5 min in the dark. Titrate

with $0.1N$ sodium thiosulfate, using fresh starch as indicator near the end-point. Report results as per cent water-soluble ferric iron on an oven-dry basis, using the per cent moisture from Sec. 3C and the formula in Sec. 6C.3, below.

6C.3—*Calculation:*

$$\frac{\text{ml thiosulfate} \times N \text{ thiosulfate} \times 5{,}585}{\text{Wt of sample (g)} \times (100 - \%\text{ moisture})} = \%\text{ water-soluble ferric iron } (Fe^{3+})$$

Sec. 7C—Free Acid

7C.1—*Reagents:*

(a) Potassium fluoride solution. To prepare, dissolve 140 g potassium fluoride in 800 ml distilled water and neutralize exactly to phenolphthalein using sodium hydroxide.

(b) Phenolphthalein indicator. To prepare, add 5 g phenolphthalein to 1 liter of 50 per cent alcohol diluted with boiled distilled water, and neutralize with sodium hydroxide.

(c) $0.05N$ sodium hydroxide (standardized).

7C.2. *Procedure.* Transfer 20 ml of the filtrate from Sec. 4C.1 (equal to 0.4 g of sample) to a 150-ml beaker. Add 60 ml of potassium fluoride solution and titrate immediately, with constant shaking, with $0.05N$ sodium hydroxide to phenolphthalein pink (use a 10-ml microburet). To compensate for the acidity of the potassium fluoride solution, run a blank, replacing the ferric sulfate solution with water. Report results as per cent free acid on an oven-dry basis, using the per cent moisture from Sec. 3C and the formula in Sec. 7C.3, below.

7C.3—*Calculation:*

$$\frac{(\text{ml NaOH} - \text{Blank}) \times N \text{ NaOH} \times 12{,}260}{\text{Wt of sample (g)} \times (100 - \%\text{ moisture})} = \%\text{ free acid (as } H_2SO_4)$$

Design and Installation of Steel Water Pipe

Committee Report

A report prepared by Committee 8310 D—Steel Pipe, to consolidate useful information on steel pipe for convenient reference. As the report is lengthy, it will be published in a number of installments, with the expectation that it will be reprinted as a unit when complete. Meanwhile, in recognition of the fact that some of the concepts included in the discussion are new to the field, comment and discussion by readers are encouraged. All pertinent discussion will be published and made part of the reprint. Discussion should be addressed to the Editor of the Journal.

INTRODUCTION

RECOGNIZING that water works engineers and technicians, contractors, consultants, designers, detail draftsmen, and specification writers, as well as advanced engineering students, would profit by the consolidation of current data necessary for the design and installation of steel water pipelines within the usual sizes, Committee 8310 D on Steel Pipe in 1943 obtained authorization from the Board of Directors to undertake such a project. The committee, in 1949, appointed one of its members, Russell E. Barnard, to act as editor-in-chief in charge of collecting and compiling the available data. With the close cooperation of all members of the committee and of the Steel Water Pipe Manufacturers Technical Advisory Committee, Mr. Barnard was able to complete a first draft of the report by January 1957. Since that time, the report has been thoroughly reviewed by the members of the committee and by numerous other authorities on the subject of steel pipe. The report is intended to provide a review of wide experience and design theory in the use of steel pipe for conveying water. It is intended to supplement but in no way supersede the requirements of AWWA standards. Application of the principles and procedures should, of course, be based upon responsible judgment.

Committee 8310 D—Steel Pipe

H. Arthur Price, *Chairman* W. W. Hurlbut, *Chairman Emeritus*

Consumer Members

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C. J. Ginder
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CHAPTER 1

Physical Characteristics of Steel Pipe

STEEL pipe has been used for water lines in the United States since about 1852 (*1*). It has solved many problems for engineers, especially when the flow and pressure were great and there were difficult natural or artificial obstacles in the path of the line.

The properties of steel which make it so useful are, first, its great strength; second, its ability to yield or deflect under a load while still offering full resistance to it; third, its ability to bend without breaking; and fourth, its resistance to shock. These four properties are combined in steel water pipe. The water works engineer should understand what they are, how they are measured, what they will do for him, and to what extent he can rely on them.

The data which follow apply to mild, intermediate, or structural-grade steel, such as is covered in AWWA standards for steel water pipe. The data apply to operation at ordinary atmospheric temperature—which is usual in water works installations—and not to high-temperature operation.

1.1. Ductility and Yield Strength

As a basis for understanding, it is well to differentiate between two classes of materials: those which are "ductile" and those which are "brittle." A "ductile" material is one that exhibits a marked plastic deformation or flow at a fairly definite stress level (yield point or yield strength) and that shows a considerable total elongation, stretch, or plastic deformation before final breakage. A "brittle" material is one in which the plastic deformation (yield point or yield strength) is not well defined and the ultimate elongation before breakage is small. Mild steel, such as used in steel water pipe, is typical of the ductile materials. In practice, these two classes of materials must be viewed differently because they act differently under load. The behavior of brittle materials will not be examined here.

The property of ductility in steel which allows it to yield or flex but not break explains why the Bouquet Canyon pipeline shown in Fig. 1.1 still (1961) operates satisfactorily after 27 years of service. Ductility likewise explains why comparatively thin-walled steel pipe, even though decreased in vertical diameter 2–5 per cent by earth pressures, performs satisfactorily when buried in deep trenches or under high fills, provided the *true* required strength has been incorporated in the design. It explains, too, why steel pipe with theoretically high localized stresses at flanges, saddles, supports, and joint-harness lug connections has performed satisfactorily for many years.

Designers who use formulas for determining stress which are based on Hooke's law find that the calculated results do not reflect the integrity exhibited by the structures illustrated here. The reason is that the *conventional* formulas apply only up to a certain stress level and not beyond. Many eminently safe structures and parts of structures contain *theoretical* stresses above this level. Therefore,

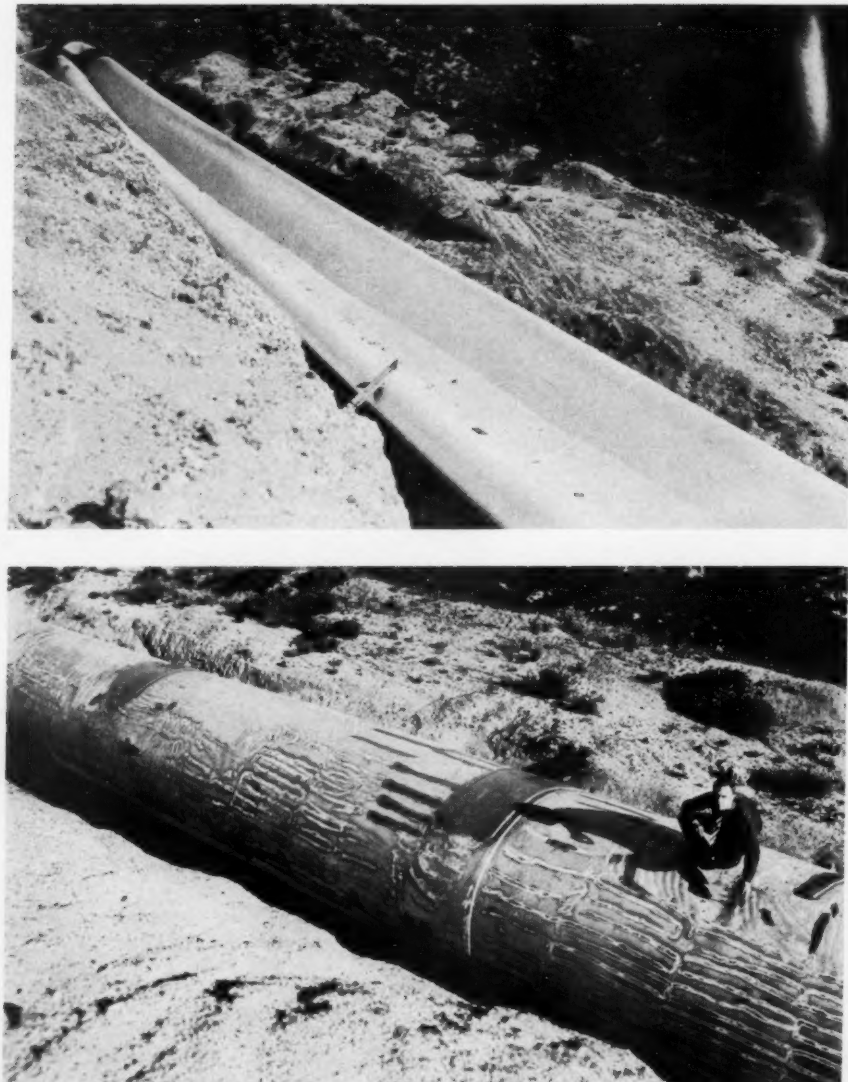

Fig. 1.1. Sections of 94-in. Bouquet Canyon Pipeline

The top photograph shows a section of pipe after it collapsed as a result of the failure of automatic vacuum-relief valves. The restored section, rounded out by water forced through under pressure, is shown at the bottom.

it is necessary to examine the behavior of steel as it is loaded from zero to the breaking point and observe what actually happens.

The physical properties of steel (yield strength and ultimate tensile strength) used as the basis for its purchase are determined from tension tests made on a standard specimen pulled in a tensile testing machine. The properties thus measured also form the basis for design.

The "strength" of ductile materials, speaking in terms of design, is defined by the yield strength as measured by the lower yield point, where one exists, or by the American Society for Testing Materials (ASTM) offset yield stress, where a yield point does not exist. For steel usually used in water pipe, the yield strength is fixed by specification as the stress due to a load causing a 0.5 per cent extension of the gage length. The point is shown in Fig. 1.2. The yield strength of steel is considered to be the same for either tension or compression loads.

"Ductility" of steel is measured as an elongation or stretch under a tension load in a testing machine. "Elongation" is a length measurement change under this load and is expressed as a percentage of the original gage length of the test specimen.

1.2. Stress and Strain

Speaking nontechnically, the terms "stress" and "strain" frequently are used synonymously. In engineering, however, they are not synonymous at all. "Stress" is a figure obtained by dividing a load by an area. "Strain" is a length change. The relation between stress and strain is very important to the designer.

A stress-strain diagram for any given material is a graph showing the strain (or stretch per unit of length) which occurs when the material is under a given load or stress. For example, consider a bar of steel being pulled in a testing machine with suitable instrumentation for measuring the load and indicating the dimensional changes. It is found that

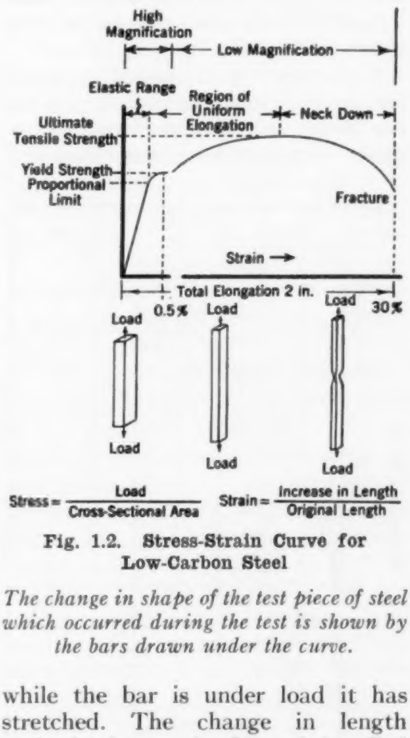

Fig. 1.2. Stress-Strain Curve for Low-Carbon Steel

The change in shape of the test piece of steel which occurred during the test is shown by the bars drawn under the curve.

while the bar is under load it has stretched. The change in length under load per unit of length is called "strain" or "unit strain," which is usually expressed as percentage elongation or, in stress analysis, microinches (μin.) per inch (1 μin. = 0.000001 in.). The values of strain are plotted along the horizontal axis of the stress-strain diagram. For purposes of plot-

ting, the load is converted into units of stress, in pounds per square inch, by dividing the load in pounds by the *original* area of the bar in square inches. The values of stress are plotted along the vertical axis of the diagram. The result is a conventional stress-strain diagram. Because the stress was obtained by always dividing the load by the *original* area of the bar, the stress appears to reach a peak and then diminish as the load increases.

If the stress is calculated by dividing the load by the *actual* area of the bar as it decreases in cross section under increasing load, it is found that the *true* stress does not ever decrease. Figure 1.3 is a real stress-strain diagram, in which both true stress and true strain have been calculated. As the conventional stress-strain diagram is used commercially, however, only that type will be employed in this discussion.

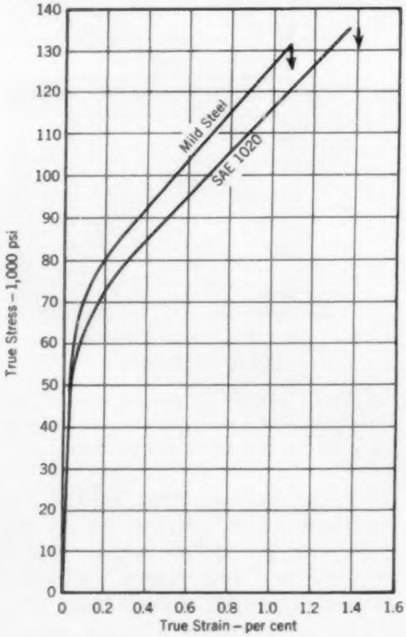

Fig. 1.3. True Stress-Strain for Low-Carbon Steel

Unlike for conventional stress-strain curves, both true stress and true strain have been calculated for the curves shown.

Figure 1.2 shows various parts of a pure-tension stress-strain curve for low-carbon steel, such as is used in water works pipe. The change in shape of the test piece during the test is shown by the bars drawn under the curve. As the bar stretches, the cross section decreases in area up to the maximum tensile strength, at which point local reduction of area, or "necking in," takes place.

Many of the steels used in construction have stress-strain diagrams of the general form shown in Fig. 1.2, while many other steels used structurally and for machine parts have much higher yield and ultimate strengths, with reduced ductility. Still other useful engineering steels are quite brittle. In general, the low-ductility steels must be utilized at relatively low strains, even though they may have high strength.

The ascending line in the left-hand portion of the graph in Fig. 1.2 is straight or nearly straight and has an easily recognized slope with respect to the vertical axis. The break in the curve is rather sudden. For this type of curve, the point where the first deviation from a straight line occurs marks the "proportional limit" of the steel. The yield strength is at some higher stress level in such steel.

Stresses and strains which fall on the straight portion of the ascending line are said to be in the elastic range. Steels loaded to create stresses or strains within that range return pre-

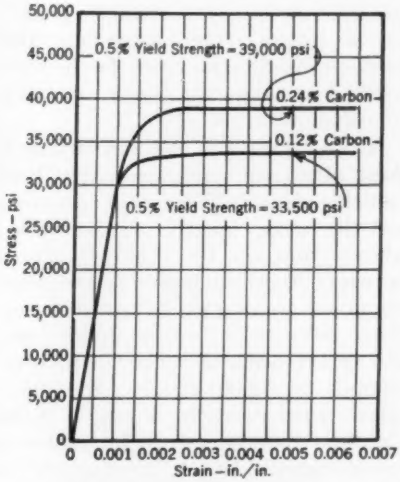

Fig. 1.4. Stress-Strain Curves for Medium-Carbon Steel

The curves show the "elastic-plastic" range for two grades of carbon steel.

cisely to their original length when the load is removed. Exceptions may occur with certain kinds and conditions of loading not usually encountered in water works installations. It is also true, within this range, that the stress increases in direct proportion to the strain, and equal increments of load add equal increments of strain. The "modulus of elasticity," as commonly defined, is the slope of the ascending straight portion of the stress-strain diagram. The modulus of elasticity of steel is about 30,000,000 psi, which means that for each increment of load that creates a strain or stretch of 1 μin. per inch of length, a stress of 30 psi is imposed on the steel cross section ($30{,}000{,}000 \times 0.000001 = 30$). Nearly all engineering formulas involving stress calculation presuppose a loading such that working stresses as calculated will be below the proportional limit.

Immediately above the proportional limit, between that point and the 0.5 per cent extension-under-load yield strength of the material (Fig. 1.2) lies a portion of the stress-strain diagram which is becoming of more and more importance to the designer. For lack of a better description, it may be termed the "elastic-plastic" range of the material. (Typical stress-strain curves with this portion magnified are shown in Fig. 1.4 for two grades of carbon steels used for water pipe.) Electric resistance strain gages are providing a means of studying the elastic-plastic segment of the curve. These and associated instruments act as a kind of microscope which tremendously magnifies the curve and allows minute examination in a manner not possible before their development.

Investigation in the elastic-plastic range became a necessity, for instance, in order to determine and explain the successful functioning of thin steel flanges on thin steel pipe (*2*). *It should be understood that the range in question is safe only for certain types of apparatus, structures, or parts of structures.* For example, it is safe for the "hinge points" or "yield hinges" in steel ring flanges on steel pipe, for "hinge points" in structures where local yielding or relaxation of stress must occur, and for bending in the wall of pipe under earth load in trenches or under high fills. It is *not* safe as a principal tension stress in the walls of pipe or pressure vessels, or in other situations, where the accompanying deformation is uncontrolled or cannot be tolerated.

Figure 1.5 shows the elastic and plastic portions of a stress-strain curve for a steel stressed to a given level. Figure 1.6 shows graphically

how a completely fictitious stress is determined by a formula based on Hooke's law, if the total strain is multiplied by the modulus of elasticity. The actual stress is determined by using only the elastic strain with the modulus of elasticity, but there is at present no way to separate theoretically the elastic and plastic strains in a structure. The only alternative is to take the total measured strain as indicated by strain gages and then determine the actual stress from the stress-strain curve, as shown in Fig. 1.7.

1.3. Strain in Design

A concept of designing on a basis of strain is fairly easy to grasp. It is evident that complete analysis of a structure becomes more logical when considered in terms of strain as well as stress. For example, it has long been known that apparent stresses calculated by use of classic formulas based on the theory of elasticity are

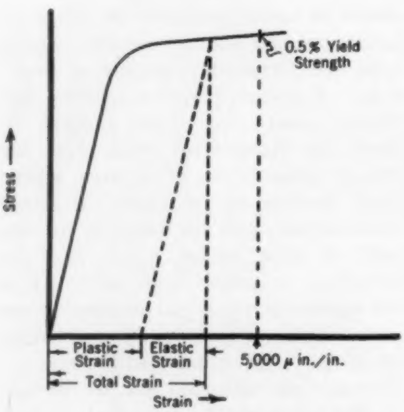

Fig. 1.5. Plastic and Elastic Strains

Shown are the elastic and plastic portions of a stress-strain curve for a steel stressed to a given level.

greatly in error at "hinge point" stress levels. The error near the yield-strength stress can be demonstrated by use of the classic approach to calculate it.

By specification, the yield-strength load of a steel specimen is that load which causes a 0.5 per cent extension of the gage length. It has been shown that, in the elastic range, a stress of 30 psi is imposed on the cross-sectional area for each microinch-per-inch increase in length under load. As an extension of 0.5 per cent corresponds to 5,000 μin./in., the *calculated* yield-strength stress is $5{,}000 \times 30 = 150{,}000$ psi. The *measured* yield-strength stress, however, is on the order of 30,000–35,000 psi, or about one-fourth of the calculated stress.

In this connection, it is interesting to note the great leeway in *strain* between the yield strength of low- or medium-carbon steel at 0.5 per cent extension under load and the specified ultimate strength at 30 per cent elongation. This has a decided bearing on true safety. The specified yield strength corresponds to a strain of 5,000 μin./in. In order to pass the specification requirement of 30 per cent elongation, however, the strain at ultimate strength must be not less than 0.3 in./in., or 300,000 μin./in. The ratio of strain at ultimate to strain at yield strength is as 300,000 is to 5,000, or 60:1. On a stress basis, from the stress-strain diagram, the ratio of ultimate strength to yield strength is 50,000:30,000, or only 1.67:1. Actually, soft steels such as are used in water works pipe show nearly linear stress-strain diagrams up to the yield level, after which strains of 10–20 times the elastic yield strain occur with no increase in

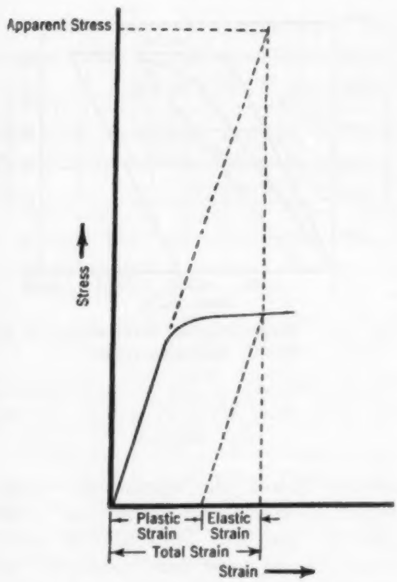

Fig. 1.6. Actual and Apparent Stresses

If the total strain is multiplied by the modulus of elasticity, the stress determined by use of a formula based on Hooke's law is fictitious.

actual load. Tests on bolt behavior under tension substantiate this statement (*3*). The ability of bolts to hold securely and safely, especially under vibration conditions, when they are drawn into the region of the yield, is easily explained by the strain concept but not by the stress concept. Actually, the bolts act somewhat like extremely stiff springs at the yield strength level.

1.4. Analysis Based on Strain

In some structures, and in many welded assemblies, there are conditions which permit initial adjustment of strain to working load but which limit the action automatically, because of either the nature of the loading or the mechanics of the assembly. Examples are, respectively, pipe under earth load and steel flanges on steel pipe. In these instances, bending stresses may be in the region of yield, but deformation is limited.

In bending, it should be recognized, there are really three distinguishable phases through which a member passes when being loaded from zero to failure. In the first phase, all fibers undergo strain less than the proportional limit in a uniaxial stress field. In this phase, a structure will act in a completely elastic fashion, to which the classic laws of stress and strain are applicable.

In the second phase, some of the fibers undergo strains greater than the proportional or elastic limit of the material in a uniaxial stress field, but a more predominant portion of the fibers undergoes strain less than the proportional limit, so that the unit still acts in an essentially elastic manner. The classical formulas for stress do not apply, but the strains can be adequately defined in this phase.

In the third phase, the fiber strains are predominantly greater than the elastic limit of the material in a uniaxial stress field. Under these conditions, the unit as a whole no longer acts in an elastic manner. The theory and formulas applicable in this phase are being developed but have not yet reached a stage where general use can be made of them. Therefore, recourse must be had to experiment.

An experimental determination of strain characteristics in bending and tension was made on medium-carbon steel similar to that required by AWWA C201 and C202 for steel water pipe. Results are shown in Fig. 1.8. It is to be noted that the

proportional-limit strains in bending are 1.52 times those in tension for the same material. Moreover, the specimen in bending showed fully elastic behavior at a strain of 1,750 μin./in., which corresponds to a calculated stress of 52,500 psi (1,750 × 30 = 52,500) when the modulus of elasticity is used. The specimens were taken from material having an actual yield of 39,000 psi. Therefore, this steel could be loaded in bending to produce strains up to 1,750 μin./in. and still possess full elastic behavior.

Steel ring flanges made of plate and fillet welded to pipe with a comparatively thin wall have been used successfully for many years in water service and form a good experience background against which to make calculations. The flanges ranged from 4 through 96 in. in diameter. Calculations were made to determine the strain which would occur in the pipe wall adjacent to the flanges. Table 1.1 shows the results.

It is to be noted from the table that, in practice, the limiting strain was

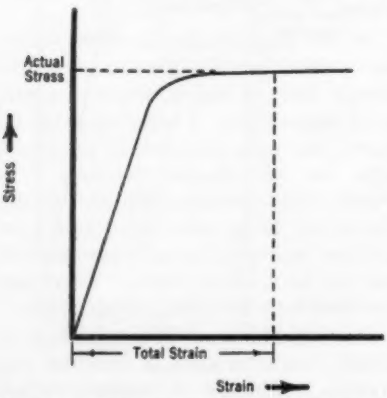

Fig. 1.7. Determination of Actual Stress

When the total measured strain is known, the actual stress can be determined by use of the stress-strain curve.

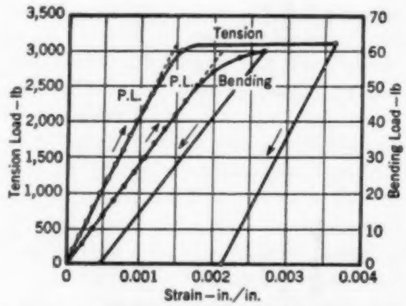

Fig. 1.8. Experimental Determination of Strain Characteristics

The proportional (P.L.) strains in bending are 1.52 times those in tension for the same material.

always below the commonly recognized yield-strength strain of 5,000 μin./in. but did approach it quite closely in at least one instance. All of these flanges are sufficiently satisfactory, however, to warrant their continued use by designers.

The idea of designing a structure on the basis of ultimate load capacity from test data rather than entirely on allowable stress is simply a return to the realistic point of view which early engineers were obliged to accept in the absence of knowledge of mathematics and statics necessary to the calculations of stresses. The recent high development of mathematical processes for stress analysis has in some instances overemphasized the importance of stress and underemphasized the importance of the overall strength of a structure.

The plastic or ductile behavior of steel in welded assemblies may be especially important. There is no logic in the argument that under no circumstances and at no point should the stress in a steel structure go beyond the elastic range. If such an argument were sound, then numerous

structural failures would have occurred and forced abandonment of much of the eminently successful current design practice. For many years, in buildings and in bridges, specifications have allowed the designer to use average or nominal stresses due to bending, shear, and bearing. The result has been local yielding around pins and rivets and at other points. This local yield is caused by stress concentrations that are neglected in the simple design formulas. The local yielding redistributes both load and stress. Plastic action is and has been depended upon to insure the safety of steel structures. Experience has shown that these average or nominal maximum stresses form a satisfactory basis for design. During the manufacturing process, the steel in steel pipe, for instance, has been forced beyond its yield strength many times. The same thing may happen again in installation. Having permitted such yielding in the mill and in the field, there is no valid basis for prohibiting it thereafter, *provided the resulting deformation has no adverse effect upon the function of the structure.*

It has been proved true, unfortunately, that the procedure of basing design solely on approximations for real stress does not always give safe results. The collapse of some structures has been traced to a kind of "trigger action" of neglected points of high stress concentrations in materials which, for one reason or another, are not ductile at these points. Even ductile materials may fail in a brittle fashion if subjected to overload in three planes at the same time. Careful attention to such conditions will result in safer design and will eliminate grossly overdesigned structures which are wasteful of both material and money. Plastic deformation, especially at key points, sometimes is the real measure of structural strength. For instance, a crack once started may be propagated by almost infinite stress, because at the bottom of the crack the material cannot yield a finite amount in virtually zero distance. Even in a ductile material the crack will continue until the splitting load is resisted elsewhere.

Plasticity underlies current design specifications to an extent not usually realized and offers promise of greater economy in construction in the future (*4*, *5*).

TABLE 1.1

Maximum Strain in Pipe Wall Developed in Practice

Standard Flange	Operating Pressure *psi*	Max. Strain *μin./in.*
A	75	1,550–3,900
	150	2,200–4,650
B	150	1,100–3,850

From Barnard (2)

1.5. Good Practice

The ordinary water line requires little stress calculation. The commonly used internal pressures for steel water pipe are given in Table 6.1 in Chap. 6. Suggested design stresses to resist other loadings are given as guides in various chapters on the different design subjects.

When designing the details of supports, wye branches, and other specials, especially for large pipe, the engineer will do well to consider the data in this chapter. They are especially applicable when the overall design of a unit is made subservient

to an analysis of concentrated localized stresses (held to low classic design limits), and formulas used beyond the range in which they apply result in an uneconomical unit.

The concept of designing on the basis of strain as well as stress will shed light on the behavior of steel and other materials in many instances where the stress concept alone offers no reasonable explanation. The action and bad effect of stress raisers—such as notches, threads, laps, broken brittle skins, and sudden changes in cross section—will be better understood. The steps to be taken in counteracting adverse effects become clearer. Design using strain as well as stress will result in safer and more economical structures than if strain is ignored. Safe *loads* are more important than "safe" stresses.

Acknowledgment

Figure 1.1 was supplied through the courtesy of Los Angeles Department of Water & Power.

References

1. Elliot, G. A. The Use of Steel Pipe in Water Works. *Jour. AWWA*, **9**:839 (Nov. 1922).
2. Barnard, R. E. Design of Steel Ring Flanges for Water Works Service—A Progress Report. *Jour. AWWA*, **42**:931 (Oct. 1950).
3. Bolt Tests—Tension Applied by Tightening Nut Versus Pure Tension. Bethlehem Steel Co., Bethlehem, Pa. (1946; *unpublished*).
4. Symposium—Plastic Strength of Structural Members. *Trans. ASCE*, Paper 2772 (1955).
5. Neal, B. G. *The Plastic Methods of Structural Analysis*. John Wiley & Sons, New York (1956).

CHAPTER 2

Uses of Steel Water Pipe

STEEL water pipe meeting the requirements of appropriate AWWA standards has been found satisfactory for the following services and applications:

1. Aqueducts (supply lines or transmission mains)
2. Inverted siphons (Fig. 2.1)
3. True siphons
4. Equalizing mains
5. Distribution mains
6. Self-supporting spans—marsh or swamp crossings
7. Self-supporting spans—stream crossings
8. On-bridge crossings
9. Underwater crossings
10. Crossings over or under highways and railroads
11. Intakes
12. Pumping station piping
13. Water treatment plant piping (Fig. 2.2)
14. Sewage pumping and plant piping
15. Pressure sewers
16. Penstocks
17. Conduits through dams
18. Power plant piping
19. Water well casing.

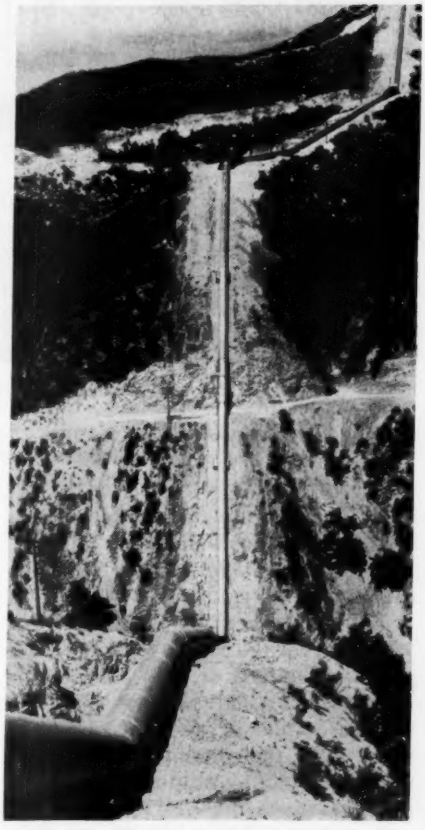

Fig. 2.1. Welded-Steel Pipe Siphon Across San Francisquito Canyon

The pipe, part of the Bouquet Canyon Project at Los Angeles, is 80–94 in. in diameter, $\frac{3}{8}$–$1\frac{1}{16}$ in. in plate thickness, and under a maximum head of 840 ft.

Because of its high ductility and strength, steel pipe has been employed safely and economically to resist stresses induced by loads and forces resulting from:

1. High pressures
2. Shifting or yielding foundations

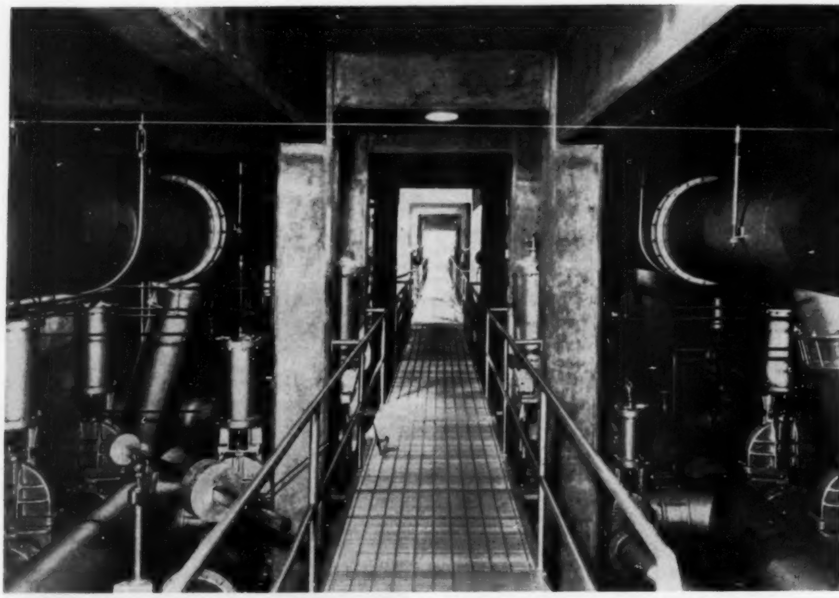

Fig. 2.2. Steel Pipe in Filtration Plant Gallery

The installation of pipe in this plant at Atlanta was made easier because of the specially designed fittings and lightweight pipe.

3. Water hammer and surge shocks
4. Deep trenches and high fills
5. Vibration from traffic or other causes
6. Impact—accidental or otherwise.

The great strength of steel pipe permits the use of thin walls with the attendant advantages. Usually though, because of practical considerations, even the minimum wall thickness chosen for an original installation possesses much unused strength. This reserve strength may make possible future safe increases in water delivery through higher pumping pressures and provide adequate safety for added exterior loads due to relocation programs for streets and highways.

Under favorable conditions, small steel pipe with service taps or small connections has been used in distribution systems.

General data on some of the notable steel pipelines have been published (*1*). Data on numerous others have appeared in the JOURNAL and other periodicals, as well as in many textbooks and engineering handbooks.

Acknowledgments

Figure 2.1 was supplied through the courtesy of Consolidated Western Steel Division, US Steel Corp., Los Angeles.

Reference

1. HINDS, JULIAN. Notable Steel Pipe Installations. *Jour. AWWA*, **46**:609 (Jul. 1954).

CHAPTER 3

Standards for Steel Pipe

STEEL water pipe may be divided into two categories according to the general method of manufacture (*mill* pipe and *fabricated* pipe). Subclassification can be made in terms of the welding process employed: none (*seamless* or *weldless*), *furnace* welding, or *electric* welding; electric welding by either of two methods, *resistance* or *fusion*—the latter process by either *electric-arc* fusion or *gas* fusion. Pipe may also be classified by the type of weld: for instance, furnace-welded pipe may be *lap* welded or *butt* welded; fusion-welded pipe may be *straight* seam or *spiral* seam. The various welding processes are described in Chap. 4, which deals with the manufacture and test of steel pipe.

3.1. AWWA Standards

The American Water Works Assn. has issued a number of standards dealing with steel pipe and appurtenances. Of the two which cover the pipe itself, AWWA C202 is for mill pipe.

Mill pipe is defined in AWWA C202 as "steel pipe of any size produced to meet finished-pipe specifications." The types and sizes covered in the standard are:

a. Seamless, $\frac{1}{8}$–30 in.

b. Furnace butt welded, $\frac{1}{8}$–4 in. OD

c. Electric resistance welded, $\frac{1}{8}$–36 in.

d. Fusion welded (straight seam), 36 in. and smaller

e. Fusion welded (spiral seam), 4–36 in.

Fabricated pipe is defined by AWWA C201 as "steel pipe fabricated from plates or sheets; the properties of the material are determined prior to fabrication." Both straight-seam and spiral-seam electric-fusion-welded pipe of any size are covered in the standard. It should be noted that, because of the wide range of diameter and wall thickness and the use of sheets or plates in a continuous process, spiral-welded pipe is classed as both mill and fabricated.

AWWA C201 covers fabricated pipe, electric fusion welded (straight or spiral seam), in sizes 4 in. and over.

3.2. Diameter and Size Designation

The terms "diameter" and "size" are used to specify steel pipe. The *size* of standard mill pipe is a nominal figure which, for 12-in. pipe and smaller, is neither the inside diameter (ID) nor the outside diameter (OD), as will be explained below. Pipe 14 in. and over is called ID or OD pipe.

3.2.1. *Mill pipe* (except spiral welded) is made by passing it between sizing rolls, which have the same diameter regardless of pipe wall thickness. The pipe therefore has a constant outside diameter, and the inside diameter varies with the wall thickness. This is a matter of pipe mill and user economy. It is also economical for all flange or mechanical-joint manufacturers, suppliers, and users to be able to have one size coupling to join given sizes of pipe regardless of wall thickness. So-called standard mill pipe is consequently standardized to the outside-diameter dimension. Special ID sizes may be furnished by some manufacturers.

Standard mill pipe of 12-in. *size* and smaller is made with an outside diameter such that the inside diameter of pipe having average wall thickness is approximately the nominal size. ("Nominal size" means the theoretical size modified by tolerances.) For example, 10-in. *size* mill pipe is $10\frac{3}{4}$-in. OD for any wall thickness but has an inside diameter of 10.192 in. when the wall is 0.279 in. thick, and a 10.020-in. ID when the wall is 0.365 in. thick.

3.2.2. Fabricated pipe may be specified in either ID or OD sizes—that is, the nominal *inside diameter* will be the size specified in the first case, or the size specified minus two wall thicknesses in the second case.

3.3. Supplementary Information Required

The AWWA Standards cover all requirements for making, testing, and inspecting steel water pipe. They are best included in job specifications by reference without embellishment. It is necessary, however, to furnish supplementary information in the job specification so that the pipe and coating standards will apply directly to that job. The points to be covered are stated in the standards themselves.

3.4. Standard Sizes

The standard sizes of steel pipe ordinarily used in water works service are shown in Tables 3.1 and 3.2.

3.5. Good Practice

The AWWA standards for pipe have been carefully prepared by recognized authorities to cover all necessary items. They are best incorporated in job specifications by reference; that is, making the standards a part of the job specifications by giving the proper numerical designations with dates and titles. The supplementary data required by the AWWA pipe standards must be given to make them applicable to the particular job. Unless great care is taken in preparing the variations, it is undesirable to modify parts of the AWWA standards or to add other requirements, because so doing usually results in manufacturing and inspection difficulties, adding to the expense of the pipe.

For pipe up to about 36 in. operating at very high pressures, or for larger pipe operating at relatively high pressures, it is well to investigate the economy of using higher-yield-point steel plate listed in Table 6.1 (Chap. 6).

List of AWWA Standards

Listed below are the AWWA standards pertaining to steel pipe which were current in 1961. Because standards are subject to change, reference should always be to the latest revision. An up-to-date list is available from American Water Works Assn., 2 Park Avenue, New York 16, N.Y. Copies of the individual AWWA standards can be purchased from AWWA at that address.

C201—Tentative AWWA Standard for Fabricated Electrically Welded Steel Water Pipe
C202—Tentative AWWA Standard for Mill-Type Steel Water Pipe
C203—AWWA Standard for Coal-Tar Enamel Protective Coatings for Steel Water Pipe
C205—AWWA Standard for Cement-Mortar Protective Coatings for Steel Water Pipe of Sizes 30 Inches and Over
C206—AWWA Standard for Field Welding of Steel Water Pipe Joints
C207—AWWA Standard for Steel Pipe Flanges
C208—AWWA Standard for Dimensions for Steel Water Pipe Fittings
C602—AWWA Standard for Cement-Mortar Lining of Water Pipelines in Place—Sizes 16 Inches and Over.

TABLE 3.1

Mill Pipe—Dimensions, Weights, and Test Pressures
(Other diameters and thinner walls are in common use and are available)

Nom.* Size *in.*	Actual Size—*in.*		Weight, Plain Ends Bare *lb/ft*	Wall Thickness—*in.*		Test Pressures—*psi*		
	OD	ID				Butt Welded	Grade A	Grade B
$\frac{1}{8}$	0.405†	0.269	0.24	0.068	$\frac{1}{16}$	700	700	700
$\frac{1}{4}$	0.540†	0.364	0.42	0.088		700	700	700
$\frac{3}{8}$	0.675†	0.493	0.57	0.091	$\frac{3}{32}$	700	700	700
$\frac{1}{2}$	0.840†	0.622	0.85	0.109	$\frac{7}{64}$	700	700	700
$\frac{3}{4}$	1.050†	0.824	1.13	0.113		700	700	700
1	1.315†	1.049	1.68	0.133		700	700	700
$1\frac{1}{4}$	1.660†	1.380	2.27	0.140	$\frac{9}{64}$	800	1,000	1,100
$1\frac{1}{2}$	1.900†	1.610	2.72	0.145		800	1,000	1,100
2	2.375†	2.067	3.65	0.154	$\frac{5}{32}$	800	1,000	1,100
$2\frac{1}{2}$	2.875†	2.469	5.79	0.203	$\frac{13}{64}$	800	1,000	1,100
3	3.500†	3.068	7.58	0.216	$\frac{7}{32}$	800	1,000	1,100
	3.500	3.250	4.51	0.125	$\frac{1}{8}$		1,300	1,500
	3.500	3.188	5.58	0.156	$\frac{5}{32}$		1,600	1,900
	3.500	3.124	6.63	0.188	$\frac{3}{16}$		1,900	2,200
	3.500	3.068	7.58	0.216	$\frac{7}{32}$		2,200	2,500
	3.500	3.000	8.68	0.250	$\frac{1}{4}$		2,500	2,500
	3.500	2.938	9.67	0.281	$\frac{9}{32}$		2,500	2,500
	4.000	3.750	5.17	0.125	$\frac{1}{8}$		1,100	1,300
	4.000	3.688	6.41	0.156	$\frac{5}{32}$		1,400	1,600
	4.000	3.624	7.63	0.188	$\frac{3}{16}$		1,700	2,000
$3\frac{1}{2}$	4.000†	3.548	9.11	0.226		1,200	2,000	2,400
	4.000	3.500	10.01	0.250	$\frac{1}{4}$		2,200	2,500
	4.000	3.438	11.17	0.281	$\frac{9}{32}$		2,500	2,500
	4.500	4.250	5.84	0.125	$\frac{1}{8}$		1,000	1,200
	4.500	4.188	7.25	0.156	$\frac{5}{32}$		1,200	1,500
	4.500	4.124	8.64	0.188	$\frac{3}{16}$		1,500	1,800
	4.500	4.062	10.00	0.219	$\frac{7}{32}$		1,700	2,000
4	4.500†	4.026	10.79	0.237	$\frac{15}{64}$	1,200	1,900	2,200
	4.500	4.000	11.35	0.250	$\frac{1}{4}$		2,000	2,300
	4.500	3.938	12.67	0.281	$\frac{9}{32}$		2,200	2,500
	4.500	3.876	13.98	0.312	$\frac{5}{16}$		2,500	2,500
	5.563	5.251	9.02	0.156	$\frac{5}{32}$		1,000	1,200
	5.563	5.187	10.76	0.188	$\frac{3}{16}$		1,200	1,400
	5.563	5.125	12.49	0.219	$\frac{7}{32}$		1,400	1,700
5	5.563†	5.047	14.62	0.258			1,700	1,900
	5.563	5.001	15.87	0.281	$\frac{9}{32}$		1,800	2,100
	5.563	4.939	17.52	0.312	$\frac{5}{16}$		2,000	2,400
	5.563	4.875	19.16	0.344	$\frac{11}{32}$		2,200	2,500
	6.625	6.249	12.89	0.188	$\frac{3}{16}$		1,000	1,200
	6.625	6.187	14.97	0.219	$\frac{7}{32}$		1,200	1,400
	6.625	6.125	17.02	0.250	$\frac{1}{4}$		1,400	1,600
6	6.625†	6.065	18.97	0.280	$\frac{9}{32}$		1,500	1,800
	6.625	6.001	21.07	0.312	$\frac{5}{16}$		1,700	2,000
	6.625	5.937	23.06	0.344	$\frac{11}{32}$		1,900	2,200
	6.625	5.875	25.03	0.375	$\frac{3}{8}$		2,000	2,400

* The term "nominal" as used herein refers to a named or given dimension, as distinguished from the actual or real dimension. There are some wide differences between actual and nominal dimensions. For example, 3.5-in. standard-weight pipe has an actual outside diameter of **4.000** in., an inside diameter of **3.548** in., and a wall thickness of **0.226** in.

† Standard weight.

TABLE 3.1.—*Mill Pipe* (*contd.*)

Nom.* Size *in.*	Actual Size—*in.* OD	Actual Size—*in.* ID	Weight, Plain Ends Bare *lb/ft*	Wall Thickness—*in.*		Test Pressures—*psi* Grade A	Test Pressures—*psi* Grade B
8⅝	8.625	8.249	16.90	0.188	3/16	800	900
	8.625	8.187	19.64	0.219	7/32	900	1,100
	8.625	8.125	22.36	0.250	1/4	1,000	1,200
8	8.625	8.071	24.70	0.277		1,200	1,300
	8.625	8.001	27.74	0.312	5/16	1,300	1,500
8	8.625	7.981	28.55	0.322	21/64	1,300	1,600
	8.625	7.937	30.40	0.344	11/32	1,400	1,700
	8.625	7.875	33.04	0.375	3/8	1,600	1,800
	8.625	7.749	38.26	0.438	7/16	1,800	2,100
10¾	10.750	10.374	21.15	0.188	3/16	650	750
	10.750	10.312	24.60	0.219	7/32	750	850
	10.750	10.250	28.04	0.250	1/4	850	1,000
10	10.750	10.192	31.20	0.279	9/32	1,000	1,200
10	10.750	10.136	34.24	0.307		1,000	1,200
	10.750	10.062	38.20	0.344	11/32	1,100	1,300
10	10.750	10.020	40.48	0.365		1,200	1,400
	10.750	9.874	48.19	0.438	7/16	1,500	1,700
12¾	12.750	12.312	29.28	0.219	7/32	600	700
	12.750	12.250	33.38	0.250	1/4	700	800
	12.750	12.188	37.45	0.281	9/32	800	950
	12.750	12.126	41.51	0.312	5/16	900	1,000
12	12.750	12.090	43.77	0.330		1,000	1,200
	12.750	12.062	45.55	0.344	11/32	1,000	1,200
12	12.750	12.000	49.56	0.375	3/8	1,100	1,200
	12.750	11.938	53.56	0.406	13/32	1,100	1,300
	12.750	11.874	57.53	0.438	7/16	1,200	1,400
Actual Size *in.*	**OD *in.***	**ID *in.***	**Weight, Plain Ends Bare *lb/ft***	**Wall Thickness—*in.***		**Test Pressures—*psi* Grade A**	**Test Pressures—*psi* Grade B**
14	14.000	13.500	36.71	0.250	1/4	650	750
	14.000	13.438	41.21	0.281	9/32	700	850
	14.000	13.376	45.68	0.312	5/16	800	950
	14.000	13.312	50.14	0.344	11/32	900	1,000
	14.000	13.250	54.57	0.375	3/8	950	1,100
	14.000	13.124	63.37	0.438	7/16	1,100	1,300
	14.000	13.000	72.09	0.500	1/2	1,300	1,500
16	16.000	15.500	42.05	0.250	1/4	550	650
	16.000	15.438	47.22	0.281	9/32	650	750
	16.000	15.376	52.36	0.312	5/16	700	800
	16.000	15.312	57.48	0.344	11/32	750	900
	16.000	15.250	62.58	0.375	3/8	850	1,000
	16.000	15.124	72.72	0.438	7/16	1,000	1,100
	16.000	15.000	82.77	0.500	1/2	1,100	1,300

* The term "nominal" as used herein refers to a named or given dimension, as distinguished from the actual or real dimension.

TABLE 3.1.—*Mill Pipe* (*contd.*)

Actual Size *in.*	OD *in.*	ID *in.*	Weight, Plain Ends Bare *lb/ft*	Wall Thickness—*in.*		Test Pressures—*psi*		
						Grade A	Grade B	Grade X-42
18	18.000	17.500	47.39	0.250	1/4	500	600	
	18.000	17.438	53.22	0.281	9/32	550	650	
	18.000	17.376	59.03	0.312	5/16	600	750	
	18.000	17.312	64.82	0.344	11/32	700	800	
	18.000	17.250	70.59	0.375	3/8	750	900	
	18.000	17.124	82.06	0.438	7/16	900	1,000	
	18.000	17.000	93.45	0.500	1/2	1,000	1,200	
20	20.000	19.500	52.73	0.250	1/4	450	500	
	20.000	19.438	59.23	0.281	9/32	500	600	
	20.000	19.376	65.71	0.312	5/16	550	650	
	20.000	19.312	72.16	0.344	11/32	600	700	
	20.000	19.250	78.60	0.375	3/8	700	800	
	20.000	19.124	91.41	0.438	7/16	800	900	
	20.000	19.000	104.13	0.500	1/2	900	1,000	
22	22.000	21.376	72.38	0.312	5/16	500	600	
	22.000	21.312	79.51	0.344	11/32	550	650	
	22.000	21.250	86.61	0.375	3/8	600	700	
	22.000	21.124	100.75	0.438	7/16	700	850	
	22.000	21.000	114.81	0.500	1/2	800	950	
24	24.000	23.500	63.41	0.250	1/4	400	450	790
	24.000	23.438	71.25	0.281	9/32	400	500	890
	24.000	23.376	79.06	0.312	5/16	450	550	990
	24.000	23.312	86.85	0.344	11/32	500	600	1,090
	24.000	23.250	94.62	0.375	3/8	550	650	1,190
	24.000	23.188	102.37	0.406	13/32	600	700	1,280
	24.000	23.124	110.10	0.438	7/16	650	750	1,380
	24.000	23.000	125.49	0.500	1/2	750	850	1,580
26	26.000	25.500	68.75	0.250	1/4			730
	26.000	25.438	77.25	0.281	9/32			820
	26.000	25.376	85.73	0.312	5/16			910
	26.000	25.312	94.19	0.344	11/32			1,010
	26.000	25.250	102.63	0.375	3/8			1,100
	26.000	25.188	111.05	0.406	13/32			1,190
	26.000	25.124	119.44	0.438	7/16			1,280
	26.000	25.062	127.82	0.469	15/32			1,370
	26.000	25.000	136.17	0.500	1/2			1,460
28	28.000	27.500	74.09	0.250	1/4			680
	28.000	27.438	83.26	0.281	9/32			760
	28.000	27.376	92.41	0.312	5/16			850
	28.000	27.312	101.53	0.344	11/32			930
	28.000	27.250	110.64	0.375	3/8			1,020
	28.000	27.188	119.72	0.406	13/32			1,100
	28.000	27.124	128.79	0.438	7/16			1,190
	28.000	27.062	137.83	0.469	15/32			1,270
	28.000	27.000	146.85	0.500	1/2			1,360

TABLE 3.1.—*Mill Pipe* (*contd.*)

Actual Size *in.*	OD *in.*	ID *in.*	Weight, Plain Ends Bare *lb/ft*	Wall Thickness—*in.*		Test Pressures of Grade X-42 *psi*
30	30.000	29.500	79.43	0.250	$\frac{1}{4}$	630
	30.000	29.438	89.27	0.281	$\frac{9}{32}$	710
	30.000	29.376	99.08	0.312	$\frac{5}{16}$	790
	30.000	29.312	108.88	0.344	$\frac{11}{32}$	870
	30.000	29.250	118.65	0.375	$\frac{3}{8}$	950
	30.000	29.188	128.40	0.406	$\frac{13}{32}$	1,030
	30.000	29.124	138.13	0.438	$\frac{7}{16}$	1,110
	30.000	29.062	147.84	0.469	$\frac{15}{32}$	1,190
	30.000	29.000	157.53	0.500	$\frac{1}{2}$	1,270
32	32.000	31.500	84.77	0.250	$\frac{1}{4}$	600
	32.000	31.438	95.28	0.281	$\frac{9}{32}$	670
	32.000	31.376	105.76	0.312	$\frac{5}{16}$	740
	32.000	31.312	116.22	0.344	$\frac{11}{32}$	820
	32.000	31.250	126.66	0.375	$\frac{3}{8}$	890
	32.000	31.188	137.08	0.406	$\frac{13}{32}$	960
	32.000	31.124	147.48	0.438	$\frac{7}{16}$	1,040
	32.000	31.062	157.86	0.469	$\frac{15}{32}$	1,110
	32.000	31.000	168.21	0.500	$\frac{1}{2}$	1,190
34	34.000	33.500	90.11	0.250	$\frac{1}{4}$	560
	34.000	33.438	101.28	0.281	$\frac{9}{32}$	630
	34.000	33.376	112.43	0.312	$\frac{5}{16}$	700
	34.000	33.312	123.56	0.344	$\frac{11}{32}$	770
	34.000	33.250	134.67	0.375	$\frac{3}{8}$	840
	34.000	33.188	145.76	0.406	$\frac{13}{32}$	910
	34.000	33.124	156.82	0.438	$\frac{7}{16}$	980
	34.000	33.062	167.87	0.469	$\frac{15}{32}$	1,050
	34.000	33.000	178.89	0.500	$\frac{1}{2}$	1,120
36	36.000	35.500	95.45	0.250	$\frac{1}{4}$	530
	36.000	35.438	107.29	0.281	$\frac{9}{32}$	600
	36.000	35.376	119.11	0.312	$\frac{5}{16}$	660
	36.000	35.312	130.90	0.344	$\frac{11}{32}$	730
	36.000	35.250	142.68	0.375	$\frac{3}{8}$	790
	36.000	35.188	154.43	0.406	$\frac{13}{32}$	860
	36.000	35.124	166.17	0.438	$\frac{7}{16}$	930
	36.000	35.062	177.88	0.469	$\frac{15}{32}$	990
	36.000	35.000	189.57	0.500	$\frac{1}{2}$	1,060

TABLE 3.2

Fabricated Pipe, 4–28 Inches OD
(Dimensions, Weights, and Test Pressures)*

Nom. Size, OD *in.*	Wall Thickness *in.*	Weight *lb/ft*	Test pressure *psi*
4	0.105	4.3	1,000
	0.135	5.5	1,200
4½	0.105	4.9	900
	0.135	6.2	1,000
6	0.105	6.6	600
	0.135	8.4	800
	0.188	11.6	1,100
	0.219	13.5	1,300
6⅝	0.105	7.3	550
	0.135	9.3	700
	0.188	12.8	1,000
	0.219	14.9	1,200
8	0.105	8.8	450
	0.135	11.3	600
	0.179	14.9	800
	0.188	15.6	850
	0.239	19.8	1,100
8⅝	0.105	9.5	400
	0.135	12.2	550
	0.179	16.1	750
	0.188	16.8	750
	0.239	21.4	1,000
10	0.135	14.2	450
	0.179	18.7	650
	0.188	19.6	700
	0.239	24.9	850
10¾	0.135	15.3	400
	0.179	20.2	600
	0.188	21.1	650
	0.239	26.8	800
12	0.135	17.1	400
	0.179	22.5	550
	0.188	23.6	550
	0.239	30.0	700
12¾	0.135	18.1	350
	0.179	24.0	500
	0.188	25.1	500
	0.239	31.9	650
14	0.135	19.9	350
	0.179	26.4	450
	0.188	27.6	450
	0.239	35.1	600
16	0.135	22.8	300
	0.179	30.2	400
	0.188	31.6	400
	0.239	40.2	550
	0.250	42.0	550
	0.312	52.3	700
18	0.135	25.7	250
	0.179	34.0	350
	0.188	35.6	350
	0.239	45.3	450
	0.250	47.3	500
	0.312	59.0	600
20	0.135	28.6	250
	0.179	37.8	300
	0.188	39.6	350
	0.239	50.4	400
	0.250	52.7	450
	0.312	65.7	550
	0.375	78.5	700
22	0.179	41.7	300
	0.188	43.6	300
	0.239	55.5	400
	0.250	58.0	400
	0.312	72.3	500
	0.375	86.6	600
24	0.179	45.5	250
	0.188	47.6	300
	0.239	60.6	350
	0.250	63.4	350
	0.312	79.0	450
	0.375	94.6	550
	0.438	110.0	650
	0.500	125.4	750
26	0.179	49.3	250
	0.188	51.6	250
	0.239	65.7	300
	0.250	68.7	350
	0.312	85.7	400
	0.375	102.6	500
	0.438	119.4	600
	0.500	136.1	700
28	0.179	53.1	250
	0.188	55.6	250
	0.239	70.8	300
	0.250	74.0	300
	0.312	92.4	400
	0.375	110.6	450
	0.438	128.7	550
	0.500	146.8	650

* Other diameters and wall thicknesses can be furnished by some manufacturers.

Relation Between Aquifer Permeability and Improvement Achieved by Well Stimulation

Louis Koenig

A contribution to the Journal by Louis Koenig, Research Consultant, San Antonio, Tex. This article is the fourth of a series by the author on various aspects of well stimulation. Earlier articles in this series were published in the March, May, and December 1960 issues of the Journal.

In previous articles of this series on well stimulation practice,[1-3] brief mention was made of the fact that the permeabilities of aquifers vary over a considerable range. It was suggested that the permeability associated with a well might have some bearing on the improvement achieved by stimulation, and that some of the differences in the performance of stimulation methods as surveyed might arise through differences in permeabilities. It was decided to explore that possibility and evaluate it in numerical terms; the methods used and conclusions reached are presented below.

Relationship for Surveyed Cases

The relationships between permeation factor and A/B ratio for all cases in the study for which the necessary data were available are shown in Fig. 1. It should be stressed that the term "permeation factor"[1] corresponds to the permeability coefficient P_f in the modified Thiem formula for equilibrium radial flow.* Table 1 shows, for various values of the permeation factor, the production, the specific capacity, and the specific capacity per foot of saturated aquifer for certain reasonable well conditions.

It is evident from Fig. 1 that there is some sort of a trend to higher improvement ratios at lower permeation factors. This is particularly evident for shooting and fracturing. Such a trend is not so clear in surging, vibratory explosion, or pressure acidizing, although, if one follows the maximum improvement reached at each permeation factor, a distinct trend is noticeable even in these methods.

Trend in Simple Models

Some qualitative theoretical reason may be sought for the trend referred to above. Consider, for example, fracturing or shooting, which have the effect of creating fissures in the aquifer through which water may enter. In an aquifer where the matrix of the rock is of very low permeability, such as in massive limestones, whatever conductivity the aquifer possesses for water comes from the fissures in the

* In this connection it should be mentioned that an earlier article [1] contains a significant typographical error, in that it states (col. 1, p. 339): ". . . observation wells other than the producing well were reported in the survey." The statement should read: ". . . observation wells other than the producing well were *not* reported in the survey."

matrix. If there are but a few small fissures leading through the impermeable matrix rock into the well, then the well production will be very low and the measured permeation factor before treatment will be very low. Fracturing or shooting of such a well will create one or more fissures of high conductivity, and, because the ratio of the conductivity of the created fissure to that of the natural fissures will be very high, a high improvement ratio will result.

The trend of the improvement ratio can be computed and qualitatively evaluated for a theoretical model. Assume a simple linear flow model with a rectangular cross section in which a horizontal fracture is created extending across the width of the section. The original cross section may be a homogeneous porous matrix or it may itself contain natural or artificial fissures. Flow in the model after fracturing will conform to the law of parallel flow [4] which states:

$$p_a = \frac{\Sigma p_i A_i}{\Sigma A_i}$$

in which p_a is the permeability of the composite system, p_i is the permeability of the ith layer, and A_i is the area of the ith layer. For the model chosen the formula

$$p_a = \frac{p_b(m_b - m_f) + p_f m_f}{m_b}$$

in which p_b is the permeability of the model before fracturing (gpd/sq ft), m_b is the thickness of the model before fracturing (in.), p_f is the permeability of the fracture (gpd/sq ft), and m_f is the thickness of the fracture (in.).

From the Poiseuille law for capillary flow, one may derive an expression for the permeability of an open (unpropped) fracture [4]:

$$p_f = 9.75 \times 10^8\, m_f^2.$$

By combining the above relationships and using the identity

$$\frac{p_a}{p_b} = \frac{P_{f(a)}}{P_{f(b)}} = \frac{A}{B}$$

which is the improvement ratio used, in previous articles of this series,[1,2] as a criterion for stimulation performance, one obtains

$$\frac{A}{B} = \frac{m_b - m_f}{m_b} + \frac{9.75 \times 10^8\, m_f^3}{p_b m_b}.$$

If it is assumed that there is one fracture 0.005 in. thick in each 10 ft of face, then $m_f = 0.005$, $m_b = 120$, and

$$\frac{A}{B} = 0.99996 + \frac{1.015}{p_b}.$$

This equation is represented by the dashed line in the fracturing section of Fig. 1. It may be startling to realize that in 10 ft of face of a permeability of 1 gpd/sq ft half of the flow comes from a fracture only 0.005 in. thick. This also qualitatively demonstrates the importance of natural cracks and fissures in conducting water through dense rocks such as limestones, where, at a permeability of say 0.001, of every 1,000 gal 999 gal would come from the

TABLE 1

Production Characteristics of a 10-in. Well at Various Permeabilities

Permeation Factor *gpd/sq ft*	Specific Capacity—*gpm/ft*		Production* *gpm*
	Per Foot of Saturated Aquifer	100 ft of Saturated Aquifer	
0.01	5×10^{-6}	5×10^{-4}	0.02
1.0	5×10^{-4}	0.05	1.68
10	5×10^{-3}	0.56	16.8
100	0.056	5.6	168
10,000	5.62	562	16,850

* 100-ft aquifer; 30-ft drawdown.

tiny fissure and less than 1 gal from the matrix rock itself.

The calculation confirms the expectation that improvement ratios for fracturing should decrease as permeabilities increase. The actual location of the line on the graph will depend on the parameters chosen for the model, especially p_f, which is much greater in the hypothetical example than in an actual propped fracture.

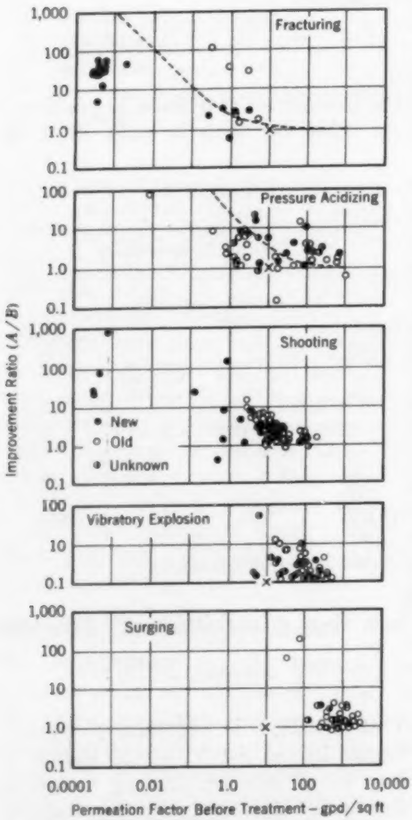

Fig. 1. Relation of Permeability to Improvement Ratio for Various Treatment Methods

Dashed curves in pressure-acidizing and hydraulic-fracturing portions represent the theoretical trend as computed for a simple model in the text.

Similarly, in acidizing or surging a fine-pored matrix rock, the removal of an amount of material sufficient to double or triple the diameter of very fine pores will increase the diameter of large pores only slightly.

Because the permeability is roughly proportional to the square of the diameter of the pore, the effect must be much greater on small pores than on large pores. Formulas are available to develop numerical values for this statement, again for a simple linear model. The model considered here will be a porous rock composed of grains of identical size such that the effective diameter of the pores is the same as the effective diameter of the grains.

A number of formulas have been proposed in the literature to compute the permeability of a formation on the basis of grain size. All of them show the permeability as roughly proportional to the square of the grain diameter. The Fair and Hatch formula will be used here [5]:

$$P_f = \frac{3 \times 18.45 \times 10^8}{m(1-\alpha)^2(\theta/100)^2(\Sigma P/d_m)^2}$$

in which P_f is the permeability (gpd/sq ft), m is the packing factor (about 5.0), α is the porosity (fraction, taken here as 0.25), θ is the sand shape factor (6.0 for spherical grains), P is the percentage of grains held between adjacent sieves, and d_m is the geometric mean of rated sizes of adjacent sieves (cm). For purposes of illustration, the summation term may be arbitrarily simplified by assuming a uniform size of sand grain with a given diameter d.

The adjacent sieve sizes will then be $(d - \delta d)$ and $(d + \delta d)$, from which the geometric mean d_m equals d, and P equals 100. For the model, then, the equation reduces to

$$P_f = 2.85 \times 10^5 \times d^2.$$

From this formula the permeability of a structure with $d = 10^{-3}$ cm is 0.285 gpd/sq ft. If an amount of material is removed from the inside of the pore so as to enlarge its diameter to 10^{-2} cm, the new permeability will be 28.5 gpd/sq ft, or an A/B ratio of 100.

In enlarging the pore from 10^{-3} cm to 10^{-2} cm a certain amount of material was dissolved or removed. If now the same amount of material is in each case removed as an annular ring from pores of successively larger diameters, a relation between the permeability before treatment and the improvement ratio is obtained, such as shown by the dashed line in the acidizing portion of Fig. 1. The position of the line is, of course, dependent upon the amount to be removed. At the low-permeability end, the improvement ratio is almost directly proportional to the amount of material removed. At the high-permeability end, it is practically independent of the amount of material removed. This calculation confirms the hypothesis that improvement ratios should decrease as permeabilities increase. It must be cautioned, however, that the simple model chosen here is far from representing the actual mechanism in pressure acidizing. A much more sophisticated model must be used, as will be discussed later.

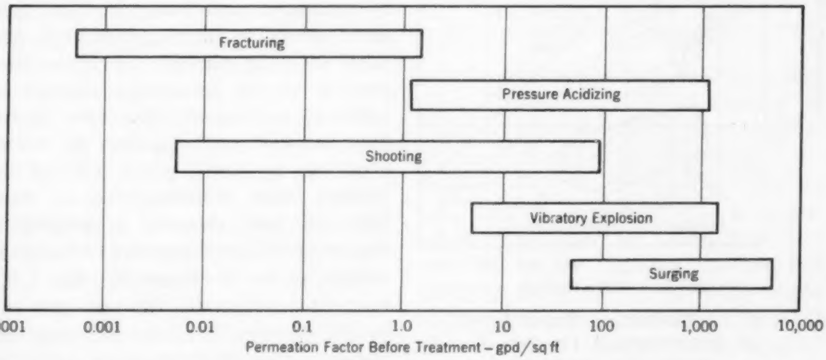

Fig. 2. Ranges of Permeation Factors Over Which Various Stimulation Methods Have Been Used

The ranges shown may well be extendable by improvements in stimulation techniques.

Nonrandomness in Permeability Ranges

Figure 1 shows not only that there is a trend toward lower improvement ratios at higher permeabilities, but also that the data for certain methods lie in higher permeability ranges than those for others. Extremes of this difference would be fracturing with no point above $P_f = 10$ gpd/sq ft and surging in which all but one point occurs above $P_f = 100$ gpd/sq ft. If there is a trend

in the data such differences in ranges favor some stimulation methods in such measures of performance as median improvement ratios. Speaking again of the extremes, the subject of why surging has not been used at lower permeation factors remains unexplored.

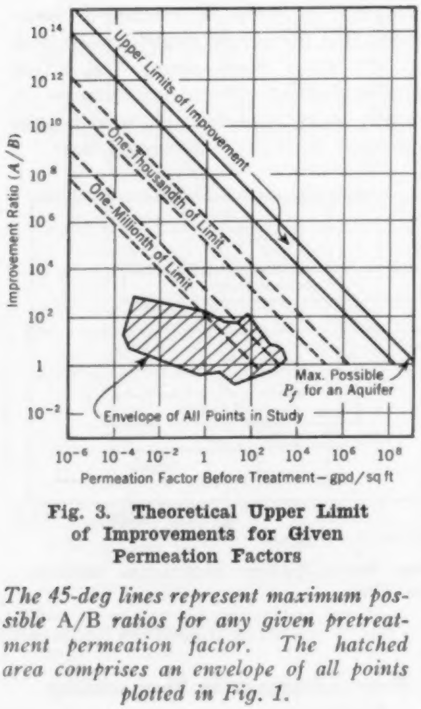

Fig. 3. Theoretical Upper Limit of Improvements for Given Permeation Factors

The 45-deg lines represent maximum possible A/B *ratios for any given pretreatment permeation factor. The hatched area comprises an envelope of all points plotted in Fig. 1.*

Possibly the water velocity achievable by surging at low permeation factors is too small to be effective, or, rather, too much power may be required for effective surging. Fracturing shows few instances in which the permeability exceeds $P_f = 10$, partly because the technique has been used so little in water wells where such permeation factors occur and partly because of the large power requirements for fracturing with present techniques in highly permeable formations. It should also be recognized that the survey sample does not cover all types of treatment conditions. For example, there seems to be no physical reason why shooting should not have been carried on at permeation factors of 1,000 as well as at 100. One reason may be that rock aquifers in which shooting is most often carried on seldom have permeabilities of more than 100, and shooting is avoided in the unconsolidated aquifers, which constitute most of those in the 1,000 range. Incidentally, it was precisely to fill the gap between shooting and surging that the vibratory-explosion method was developed, and Fig. 1 shows how it has been used to do so.

Figure 2, a condensation of Fig. 1, shows the approximate ranges of permeation factor over which the various

TABLE 2

Permeation Factors for 10-in. Wells at 1,000-ft Radius of Influence (r_e) *With Manning Flow*

Drawdown $(h_e - h_w)$ *ft*	Confined Aquifer		Unconfined Aquifer	
	m = 30 ft	m = 130 ft	h_e = 30 ft	h_e = 130 ft
	Permeation Factor (P_f)—*gpd/sq ft*			
10	2.82×10^8	7.50×10^8	4.07×10^8	11.50×10^8
20	1.99×10^8		2.79×10^8	
50		3.34×10^8		4.74×10^8

methods have been used. This does not indicate that these ranges are the limits of performance, as developments in the field may well extend the ranges for some methods in both directions.

The designation of new and old wells in Fig. 1 is made to show that new wells perform about as well as old at equal permeation factors. But new wells are not uniformly distributed in the P_f ranges, as was taken into account in an earlier article.[8]

Theoretical Limit of Improvement

Reflections on the trend of improvement with increased permeation factors lead to the question: what are the extreme limits of improvement? How far can an aquifer be improved, and how near is present performance to the limit? If one considers a horizontal aquifer of uniform thickness and confined by its upper and lower boundaries, it must be concluded that the maximum conductivity such a structure could achieve would be that shown if it was 100 per cent pores—that is, absolutely devoid of rock. Flow equations have been worked out for such structures and we will here inquire as to what would be the permeability of such a structure measured by the usual methods. The actual flow in such a system can be described by the Manning formula for rectangular ducts flowing full:

$$Q'/A = V = 1.486n^{-1}R^{2/3}S^{1/2} \ldots\ldots (1)$$

in which Q' is the flow (cfs), A is the cross-sectional area (sq ft), V is the mean velocity (fps), n is the friction coefficient (0.033 for smooth rock cuts), S is the hydraulic gradient, and R is the hydraulic radius (ft). For a rectangular cross section of width c and height m, $R = mc/(2m + 2c)$. The cross section for radial flow into a well in a confined aquifer has a top and bottom but no sides. Therefore, R is the hydraulic radius for a rectangle in which c approaches ∞, which reduces to $m/2$. The hydraulic gradient is the slope of the piezometric surface on a radius, such that $S = dh/dr$, in which r is the radial distance from center of well (ft) and h is the height of piezometric surface above the bottom of aquifer (ft). Equation 1 thus becomes

$$Q'/A = V = 1.486n^{-1}(m/2)^{2/3}(dh/dr)^{1/2} \ldots (2)$$

This may be compared with the corresponding equation for Darcy law flow:

$$Q'/A = V = Kdh/dr \ldots\ldots\ldots (3)$$

in which K is the permeability coefficient (fps-ft/ft). By substituting in the relation $Q' = AV$, converting to Q (gpd) and to the permeability coefficient P_f, and integrating between $r_w h_w$ and r, h, where $P_{f(r,c)}$ is the permeation factor for radial flow in a confined aquifer (gpd/sq ft), r_w is the radius of the well (ft), h_w is the height of the piezometric surface at the well (ft), m is the thickness of the aquifer (ft), Q is the flow (gpd), one obtains:

$$Q = \frac{3.80 \times 10^6 m^{5/3}(h - h_w)^{1/2}}{n(r_w^{-1} - r^{-1})^{1/2}} \ldots (4)$$

Equation 4 shows the flow which would be measured in an aquifer consisting of 100 per cent voids. Integration by use of the Darcy law velocity yields

$$Q = \frac{2.72mP_f(h - h_w)}{\log r/r_w} \ldots\ldots\ldots (5)$$

which is the familiar Thiem formula. It is from Eq 5 that the hydrologist, knowing Q, m, h, and r, would compute the permeability of the aquifer. Equating Eq 4 and 5 then:

$$P_f = \frac{1.40 \times 10^6 m^{2/3} \log r/r_w}{n(h - h_w)^{1/2}(r_w^{-1} - r^{-1})^{1/2}} \ldots (6)$$

one obtains the permeability that would be computed if the aquifer comprised 100 per cent pores and the flow followed the Manning formula. Where r is large (1,000 ft), the expression $h - h_w$ represents the drawdown and Eq 6 becomes, for $n = 0.033$:

$$P_{f(r,c)} = \frac{4.24 \times 10^7 m^{\frac{2}{3}}}{(h_e - h_w)^{\frac{1}{2}}} \times r_w^{\frac{1}{2}} \log \frac{r_e}{r_w} \quad (7)$$

in which r_e is the radius of influence (radius beyond which there is no detectable drawdown from the static level) and h_e is the height of the piezometric surface at r_e. A similar procedure involving open-channel flow yields, for unconfined aquifers:

$$P_{f(r,u)} = \frac{6.46 \times 10^7 (h_e^{13/3} - h_w^{13/3})^{\frac{1}{2}}}{h_e^2 - h_w^2} \times r_w^{\frac{1}{2}} \log \frac{r_e}{r_w} \quad (8)$$

It is evident that the P_f which would be measured depends on a number of the hydrologic and well-independent parameters. Taking reasonable values of these for illustration, one obtains the values in Table 2 computed for a 10-in. diameter well with r_e assumed as 1,000 ft.

Permeation factors of the order of 10^8 gpd/sq ft would be observed. As the highest permeation factors observed in the present study are about 4×10^3 gpd/sq ft, it may be concluded that the limiting factor, if there is one, is not the inability of the geometric structure to transmit more water. In other words, there is ample room for additional improvement in permeability if the means could be devised for further increasing the microscopic or macroscopic flow channels in the aquifer.

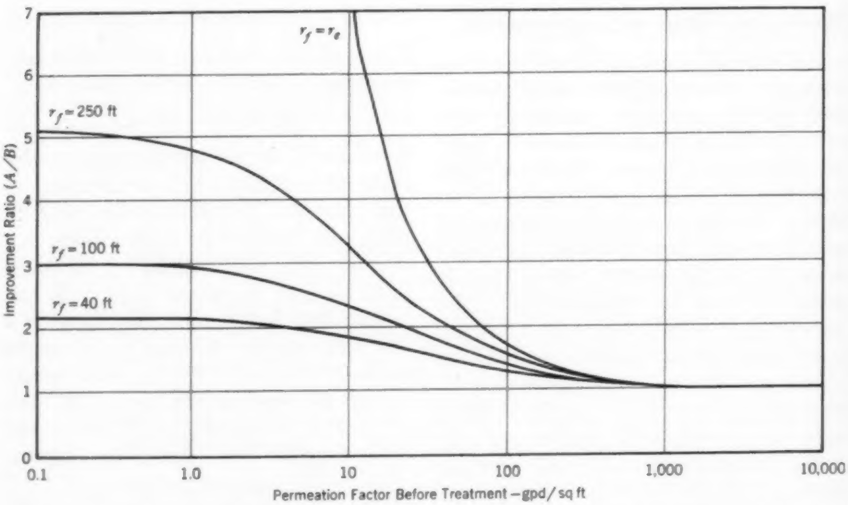

Fig. 4. Theoretical Relationship of Improvement Ratio to Permeation Factor in Fracturing

Standard values are: m_f *0.0167 ft,* p_f *40,000 gpd/sq ft,* m_0 *10 ft,* r_w *0.833 ft, and* r_e *1,000 ft;* r_f *values are as shown.*

Although no special study has been made of the subject, it is believed that a permeability of the order of 5,000 is about as high as is normally found in operating wells. Permeabilities of 20,000 and even 90,000 have been measured in aquifer samples in the laboratory, and in the present study one well was described having a permeation factor of 1.64×10^5 gpd/sq ft and a transmission factor of a 11.2×10^6 gpd/ft, although the data were not confirmed. Even these extreme permeation factors would have to be increased 1,000-fold in order to reach the theoretical upper limit, however.

Out of curiosity the piezometric profile was computed for the Darcy case and for the Manning case in a 10-in. well with $Q = 100$ gpm, $m = 5$ ft, and $P_f = 5{,}000$ gpd/sq ft. In the Darcy case the drawdown below the piezometric surface at 1,000 ft from the well would be about 7 ft. In the Manning case the same drawdown would be about 10^{-8} ft.

Figure 3 shows that the theoretical improvement limit is far from being approached in the present study even at very low permeation factors, for which the improvement ratios are relatively high. The shaded area represents the envelope surrounding all the points in Fig. 1. The 45-deg lines extending from about 10^8 and 10^9 gpd/sq ft at $A/B = 1.0$ represent the limiting improvement ratio that could be achieved at any given P_f.

Limits Dependent on Method

Although the previous section shows the absolute limits of improvement, these limits are never reached in practice, owing to the inability of the stimulation method to approach complete removal of the rock. The practical limit to improvement therefore is developed through consideration of the mechanism of the stimulation. Considerable work has been done in the petroleum production field to determine the relation between stimulation improvement and the various parameters of the stimulation method. In the petroleum industry engineers are just in the past few years beginning to predict stimulation improvement ratios. They are thus beginning to be able to tailor the stimulation job to the desired improvement ratio, and indeed to begin to discuss the "economic treatment," or the treatment that will give the maximum money return in well performance on the money spent for the treatment.

Acidizing

In a previous section a very simple model was used to compute the dependence of improvement ratio on permeability. The model assumed a porous matrix, uniform diameter of pores, and the spending of the same volume of acid in each linear unit of pore. A much more sophisticated model is necessary to represent the actual situation in the acidizing of a natural formation. The type of work now going on and the models used in studies of the subject by petroleum engineers are discussed in the literature.[6-9]

The water passages in an actual aquifer cannot be simply represented as a homogeneous structure of uniform pores. There are at least three different physical structures which, in varying degrees, make up an aquifer. One of these is a relatively homogeneous porous matrix; the second is composed of natural or artificial fissures which have diameters much greater than those of the pores; and the third is an area of small, indefinite thickness circumferential to the well in which the conductivity of the natural formation has been damaged by the drilling

process. Not all wells involve all three situations, but all three must be investigated if all types of well characteristics are to be described. Since the flow characteristics and the flow laws for these three types of structures are different, the ground water hydrologist's laws for flow, especially surrounding a well, are in need of some reinvestigation. It can be shown for example, that when horizontal fractures intersect the well bore most of the fluid entering the well does so through the fractures and most of the fluid entering the fractures does so at the end of the fracture remote from the well.[10] Also it is quite possible—and more likely in natural fissures than in artificial fractures—that flow in these fissures more closely approximates Manning flow than Darcy flow.

Furthermore, the relationship of acid to rock removal is not so simple as a constant volume of acid for each inch of penetration. There is a competition between the rate at which acid penetrates the formation and the rate at which it spends itself in dissolving rock. The reaction rate depends on the pressure, the temperature (the heat generated in the reaction is not conducted away immediately and therefore the temperature in the pore rises), the acid concentration, the common ion effect, the ratio of volume of acid to surface area exposed, and the velocity of passage.

In the third place even in straight matrix acidizing the improvement is controlled and limited by the fact that the pores are not uniform but distributed in size. Thus most of the acid penetrates in the larger pores, penetration in the smaller pores being restricted to the immediate vicinity of the well because the linear rate of penetration is so slow that the acid increment is soon spent. Thus most of the improvement in matrix acidizing comes about through enlargement of the larger pores. As it has been shown in a previous section that much more

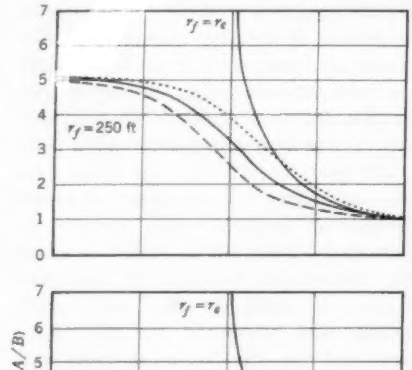

Fig. 5. Effect of Alterations in Aquifer Thickness, Fracture Permeability, or Number of Fractures per Foot of Face

Solid curves are standard values from caption of Fig. 4. Dashed curves are the same except that m_f *or* p_f *have been halved or* m_0 *has been doubled. Dotted curves are the same as solid except that* m_f *or* p_f *have been doubled or* m_0 *has been halved.*

acid is required for a given improvement ratio in large pores than in small pores, it is apparent that there is a practical limit for improvement with the volumes of acid and injection rates presently used. Furthermore, it is quite likely that matrix acidizing at present injection rates already generates pressures above that required for fracturing. Once a fracture of any appreciable size is formed, the porous matrix thereafter receives very little acid penetration.

Because of the very complicated nature of the phenomena and the newness of the techniques it has not been possible to work out acidizing improvement limits for aquifers, although the basic data are not too difficult to obtain. Computations which have been made on oil field formations with a permeability of about $P_f = 0.02$ gpd/sq ft, however, indicate a limit of 5–10-fold improvement.

Hydraulic Fracturing

In oil field technology, the technique of calculating theoretical improvement due to fracturing is more advanced than for acidizing.[10–13] Because the relations are simpler, a computation has been made over the range of interest for water well work. The basic formula for production improvement by a fracture in a homogeneous porous matrix is[14]:

$$\frac{A}{B} = \frac{\log \frac{r_e}{r_w}}{\log \frac{r_e}{r_f} + \left(1 + \frac{p_f m_f}{p_0 m_0}\right)^{-1} \log \frac{r_f}{r_w}}$$

in which m_0 is the thickness of the confined aquifer (ft), m_f is the thickness of the horizontal fracture (ft), p_0 is the permeability of the aquifer (gpd/sq ft) and p_f is the permeability of the horizontal fracture (gpd/sq ft).

Figure 4 shows the improvement ratios to be expected in a standard situation characterized by the parameters: m_f, 0.0167 ft; p_f, 40,000 gpd/sq ft; m_0, 10 ft; r_w, 0.833 ft (20-in. diameter); r_e, 1,000 ft; r_f, 40, 100, 250, and 1,000 ft.

It can be seen that in the lower ranges of permeability the improvement ratio depends heavily on the radial extent of the fracture. The radial extent of fracture is controlled by the amount and injection rate of the fracturing fluid and by its flow and leakoff characteristics, which are controlled with additives. Relations have been worked out by which fracture radius can be predicted from these parameters for typical oil field formations. From these relations combined with the theoretical improvement ratios (Fig. 4) optimum oil field fracture treatments have been worked out. The relationships developed cannot be used to predict fracture radii at such high permeabilities as those encountered in water-bearing formations, however. It therefore is not certain that fracture radii as large as 250 ft could be obtained with present techniques in, for example, an aquifer with a permeability of 10 gpd/sq ft.

In the higher ranges of permeabilities the fracture radius is of no influence, and in the model under consideration hydraulic fracturing is theoretically incapable of bringing about any appreciable improvement. Although these facts were generally known, prior to this calculation, it was not known how low in permeability this condition extended and whether in permeabilities of interest for water wells there would be any theoretical improvement. Roughly, it may be said that at a permeability of $P = 1$ gpd/sq ft, 200–500 per cent improvements are possible; at $P = 10$ gpd/sq ft, 200–300 per cent;

and at $P = 100$ gpd/sq ft, 30–70 per cent.

In Fig. 5 the effect of altering some of the parameters is shown. The upper dotted lines in each case show the effect of doubling m_f, p_f, or of halving m_0. All of these result in an increase in the improvement ratio, which at its greatest amounts to about 20 per cent for a 40-ft fracture radius, 60 per cent for 100 ft, and 135 per cent for 250 ft. Halving the fracture thickness, permeability, or number of fractures per foot of face would produce a curve displaced an equal amount downward. These magnitudes indicate that if sufficiently extensive fractures can be obtained it might be worthwhile to attempt to improve their thickness, permeability, or their frequency. There is, however, little chance with alterations of these magnitudes of accomplishing the really important desideratum of shifting the area of significant A/B ratios (2–10) up to permeation factors of 100–2,000 gpd/sq ft where most of the existing wells lie.

The present trend in the oil field technology in this direction is to attempt to increase the thickness of the fracture by increasing the ratio of propping sand to fluid thus propping the fracture further apart with packed sand. It has recently been shown, however,[15] that just the opposite approach is more fruitful. Whereas a fracture packed with 8- to 12-mesh sand would have a permeability of about 3.6×10^4 gpd/sq ft, a partial monolayer of 6-mesh particles (15–20 particles per square inch of fracture area—one side only) would give a permeability ranging from 2.3×10^6 to 0.5×10^6 gpd/sq ft, the median being 1.6×10^6 gpd/sq ft. The study takes into account the partial embedment of the propping sand in the formation under existing formation pres-

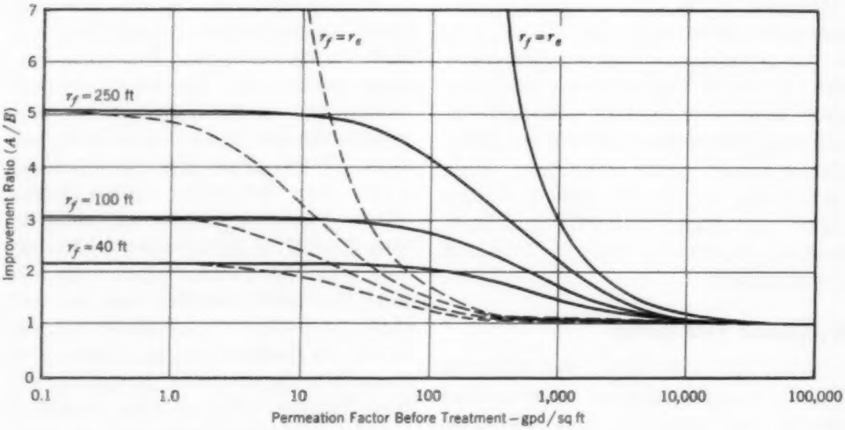

Fig. 6. Effect of Monolayer in Place of Packed Fracture

Dashed lines are based on standard values from the caption of Fig. 4. Solid lines are the same with $p_f = 1.2 \times 10^6$.

sures. Figure 6 shows the improvement ratios to be expected when all conditions are standard except that $p_f = 1.2 \times 10^6$ gpd/sq ft. Of particular importance is the extension of the range in which reasonable improvements are possible to the higher permeabilities characteristic of water well aquifers. Thus it is particularly important that the same improvement ratios achievable at $P_f = 100$ gpd/sq ft with the packed fracture are with the monolayer achievable even up to $P_f = 4{,}000$ gpd/sq ft. In view of the improvement attained and of the importance of such improvement, especially to the water industry, it is safe to say that the research and development necessary to achieve placement of such monolayers in fracture is probably already underway. In soft formations one of the main problems may be to avoid extensive imbedment of the propping agent in the formation.

Figure 7 shows the results of halving the radius of the well or the radius of influence, other parameters remaining standard. Changing the well diameter from 20 in. to 10 in. would bring about only a modest improvement—50 per cent at the very best, and much less for most situations. Also shown is the effect of halving the radius of influence. This effect is much greater. Two things should be noted in connection with Fig. 7. One is that for a given fracturing treatment the radius of fracture will increase as the permeability decreases. This means that at the lower permeabilities the actual curve for an achievable fracture radius will tend to approach the $r_f = 250$ line, whereas at higher permeabilities it will tend toward the $r_f = 40$ line. Counteracting this effect is the fact that as the permeability increases the radius of influence decreases, so that at the lower permeabilities the true achievable curve would be near the solid lines and at higher permeabilities it would approach the dotted lines. These effects can remain only qualitative until more quantitative relations have been worked out for fracture parameters at higher permeabilities.

The general conclusion is that the theoretical limits for the improvement ratio due to fracturing as conducted in the past are in the general range 3–10 at low permeation factors and about 1.5–2.3 at moderately low permeation factors (40 gpd/sq ft).

Skin Effect

In Fig. 1, values for A/B which are below the practical maximums represented for acidizing and fracturing developed in the previous two sections can be explained as failures to achieve the full development of the technique. It is quite likely that similar theoretical limits apply to surging as an action similar to acidizing in enlarging effective pore diameters, and to shooting as similar to fracturing in generating artificial fissures. The interesting question, however, is how to account for those improvements that are higher than the calculated maximums.

Because the theoretical curves were computed for certain standard parameters, some of the high improvements may be accounted for by more favorable parameters than the standard. It should be noted that the theoretical lines in the acidizing and fracturing data are indicative only of the slope to be expected; the actual position would vary with the parameters of the treatment. Although such variations may account, as has been seen, for up to a 50 per cent increase in improvement

ratio, no reasonable values of the parameters can explain improvements 10–100 times greater than theoretical.

A more likely explanation for such high improvement ratios is the so-called "skin effect."[11, 13, 16–22] The skin effect is the effect on flow, permeation factor, or other flow parameters of a relatively thin area circumferential to the well in which the permeation factor is distinctly different from that of the bulk of the formation. This difference in permeability may be brought about by damage to the formation in the drilling or the treatment process. The damage and damage zone referred to here and in the references above apply solely to a zone roughly concentric with the well bore, although in the later literature[10] the concept is extended to cover impairment of permeability—that is, damage—roughly coaxial with a fracture.

Writers on the subject have devised various measures of the skin effect and given them various names, such as "damage factor," "skin effect," "completion factor," "condition ratio," and "damage ratio." All these terms are related to the permeability of the skin zone or to its resultant effect on the production of the well as compared

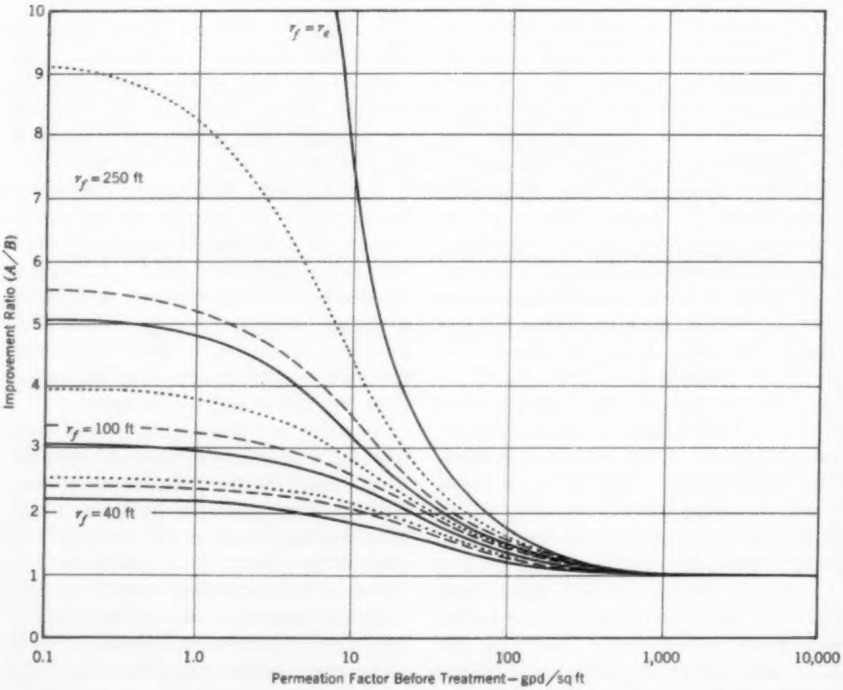

Fig. 7. Effect of Altering Radius of Well or Radius of Influence

Curves are based on standard values in caption to Fig. 4; except that r_w has been halved in dashed curves and r_e has been halved in dotted curves.

with the production from a similar formation without the skin zone. All deal with the productivity ratio Q/Q_0, in which Q is the production at a given drawdown of the actual well and Q_0 is the production at same drawdown of an identical well in the same aquifer but in which the skin effect does not exist. This ratio is numerically equal to P_f/P_T, in which P_f is the permeation factor as defined in this study and P_T is the true permeability of the undamaged formation as determined from nonequilibrium tests. If $P_f/P_T = 1$ the well is behaving as an ideal well in an undamaged formation.[1] If $P_f/P_T < 1$ there is a skin zone of low permeability around the well; and if $P_f/P_T > 1$ there is a zone around the well in which the permeability has been increased over the true permeability of the bulk of the aquifer, either through stimulation or through natural circumstances such as location of the well in a localized fissured zone.

Students of water well hydraulics will recognize still another name for this ratio, for in their science it has been named "well efficiency." As the illustrative references, which are a few out of many papers, attest, a great deal of groundwork has been done by the petroleum reservoir engineers in deducing the nature of the well environs from productivity index (specific capacity) and pressure buildup (recovery) data. These two correspond quite closely respectively to the equilibrium and the nonequilibrium data and test methods of water well hydraulics. As yet no student of water well hydraulics has taken the necessary steps to translate the comprehensive work in the oil well technology over into terms and under conditions that are applicable in water wells. This constitutes some vital unfinished business of the ground water hydrologists and engineers.

Figure 8 gives some indication of how improvement ratios greater than the maximum calculated by the simple theory may be achieved. The curves are computed from the formula for radial series flow[4]:

$$\frac{P_{f(a)}}{P_0} = \frac{A}{B} = \frac{\log \frac{r_e}{r_w}}{\log \frac{r_e}{r_z} + \frac{p_0}{p_z} \log \frac{r_z}{r_w}}$$

in which $P_{f(a)}$ is the permeation factor of composite structure (gpd/sq ft), p_0 is the permeability of unaltered formation (gpd/sq ft), r_z is the radius of altered zone (ft), and p_z is the permeability of altered zone (gpd/sq ft). For a typical 10-in. well with a 1,000-ft radius of influence, this reduces to:

$$\frac{A}{B} = \frac{3.3802}{\log \frac{1{,}000}{r_z} + \frac{p_0}{p_z} \log 2.4 r_z}.$$

It is shown that with a relatively small depth of penetration of damage the permeation factor may be reduced to as little as 10 per cent of the permeation factor for the undamaged aquifer if the permeability of the damaged zone is 1 per cent of the permeability of the bulk of the formation. The permeability of unweathered clays is of the order of 10^{-4} to 10^{-3} gpd/sq ft; that of silts is 10^{-2} to 10^{-1} gpd/sq ft. It is easy to understand therefore how a movement of silt into the region of the well bore or the invasion of the formation for a short distance with the claylike material used in drilling muds, might easily reduce the permeability of even a poor aquifer ($P_f = 10$ gpd /sq ft) to 1 per cent of its original value or less. Stimulation in such a case has only to break down a rather thin barrier of highly impervious mate-

rial in order to make the overall permeation factor increase tenfold or more. All methods of stimulation are potentially capable of removing such thin zones of reduced permeability, which may explain some of the high improvement ratios found in the study.

A visualization of what happens in stimulating two extremes of underground flow resistances is shown in Fig. 9. At the left is shown a well penetrating a formation the resistance of which is indicated by the various degrees of shading. The formation before treatment, shown at the left of the well, is fairly permeable except for a layer close to the well bore. The graph directly below that portion of the diagram shows the permeability of the formation in various zones up to the well bore. At the right of the well is shown the permeability in the various zones after a shallow stimulation treatment has removed the skin

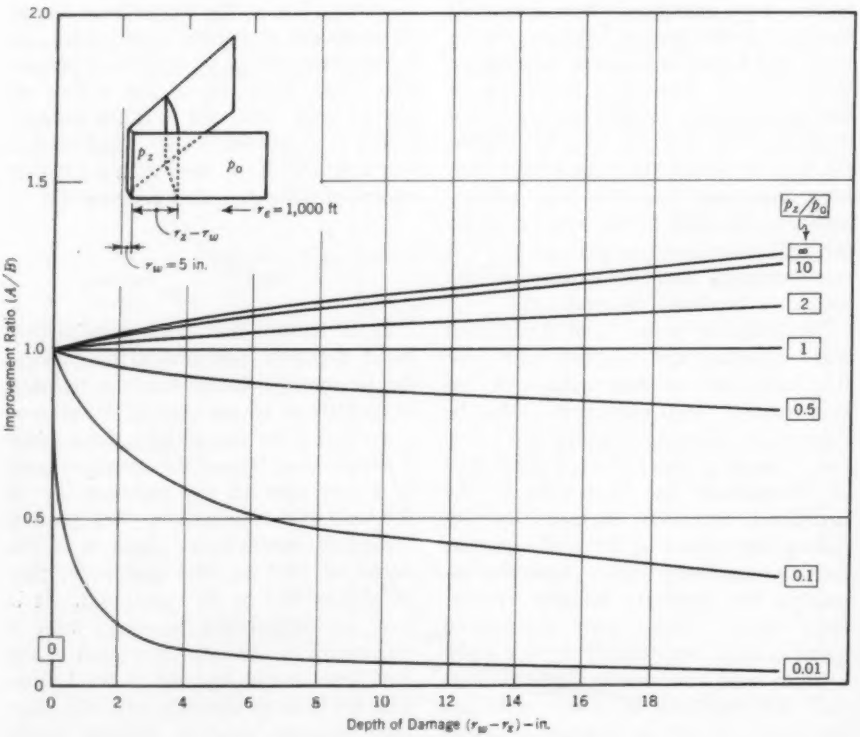

Fig. 8. Theoretical Skin Effect

Each curve shows, as lines of constant permeability ratio p_z/p_0, *the improvement ratio* A/B *for a well in a formation of permeability* p_0 *after a zone of permeability* p_z has *been created circumferential to the well. If* $p_z/p_0 < 1$ *damage has been done to the original permeability. Values greater than 1 represent improvement.*

resistance. It will be noted that the permeabilities in all zones are the same as before treatment, with the exception of the surface zone, where the permeability has been greatly increased. The drawdown curves represent roughly the conditions at identical production rates before and after treatment. A considerable portion of the drawdown before treatment occurs in the zone very close to the well. Removal of resistance in this narrow zone allows a considerable reduction in drawdown. This is because the high resistance in the zone next to the well has a great influence on the overall permeation factor.

On the right side of Fig. 9 a different condition is shown, in which the flow resistance before treatment is due to a low permeability over the entire formation. This is a bulk resistance rather than a surface resistance. In order to achieve any appreciable increase in flow under these conditions, a deep stimulation treatment is required, as it must penetrate well out into the formation and increase the permeability over a considerable distance from the well. The drawdown curves attempt to represent these conditions qualitatively. It can be seen that before treatment the zone close to the well does not have a particularly great influence on drawdown, which is distributed more through the formation than in the previous case.

The ultimate extreme in skin effect is reached in an aquifer with a highly impermeable matrix through which water movement occurs in natural fissures. If these fissures are not uniformly distributed throughout the matrix but occur in localized patches, then conditions are ideal for very erratic well performance. A well which happens to penetrate a fissured patch will have a high productivity whereas a nearby well which misses such fissures will be dry. Localization of fissures or other openings in an otherwise dense matrix can occur for a number of reasons, such as faulting, which produces a brecciated zone or opens up a joint system to allow percolation of dissolving waters. Just such a condition is the explanation for the seemingly contradictory fact that in Bexar County, Tex., where water is drawn from one of the world's most prolific aquifers, the Edwards limestone, a greater number of stimulation jobs had been done per square mile than in any similar-sized area in the study. An Edwards well is a dry hole unless it penetrates a fissured zone. Even if the well bore passes within inches of a fissure, the resistance of the massive limestone matrix is so high that no flow is obtained. A relatively shallow stimulation treatment is able to break through this skin zone to the fissure, and, as some fissures are known to be very large, the effect can be quite startling.

It would appear that stimulation in cases of skin resistance could be accomplished by shallow fracturing as well as by jet or gun perforation, which is ordinarily not considered a stimulation method, although it will produce 1-in. holes up to 12 in. from the well bore. Intelligent application of shallow-stimulation techniques where needed, however, will have to await the hydraulic research necessary to develop methods for measuring permeability profiles from nonequilibrium pumping or recovery tests. This constitutes another important piece of unfinished business in water well hydraulics.

Summary

The improvement ratios achieved by every treatment type in this study seem to decrease with increases in the permeation factor before treatment. This trend is in the proper direction based on a qualitative reasoning for fracturing and acidizing, which can be extended to include surging and shooting.

The observed points for some of the treatment methods, notably fracturing and shooting, lie in regions of lower permeability than those for other methods, especially surging. This circumstance penalizes the evaluation of the performance of those methods restricted to the higher permeabilities. Surging, vibratory explosion, and pressure acidizing are the techniques which have been used in the higher extreme of permeability range, whereas shooting and hydraulic fracturing have been used in the lower extreme.

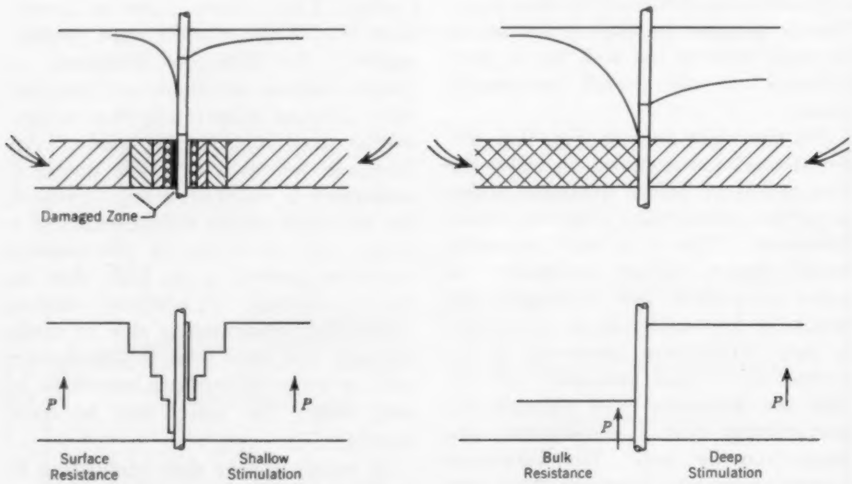

Fig. 9. Two Extremes of Flow Resistances and Their Reduction by Stimulation

Upper left: aquifer with damaged zone (indicated by shading). Upper right: aquifer with moderately low permeability throughout. The lower drawings represent permeability profiles for the two extremes.

The permeation factor is computed for an aquifer from which all solid rock has been removed, as the extreme of stimulation. This permeation factor is of the order of 10^8 gpd/sq ft. Improvement ratios achieved in wells in the study are only one-thousandth and one-millionth of this ultimate. The limiting factor is not the inability of the geometric structure to transmit more water, but the inability of the treatment method to approach complete removal of the rock.

The mechanism for pressure acidizing is complicated by a number of interrelated factors. Theoretical computations for acidizing in the petroleum industry show possible improvement ratios as high as 5:1 or 10:1.

A flow relationship for hydraulic fracturing is applied to determine the possible improvement ratios with typical fractures for formations having

permeabilities in the water well range. In the region of very poor aquifers ($P_f < 10$ gpd/sq ft) improvement ratios of 2:1 to 5:1 are indicated with present techniques. By a change in present fracturing techniques, however, it is theoretically possible to increase greatly the permeability of a fracture, and if this were brought about improvement ratios of up to 2:1 could be reached even at permeation factors of 1,000 gpd/sq ft.

Some improvement ratios found in the study were higher than those theoretically achievable; the explanation is the skin effect—a highly impermeable thin zone directly around the well. Terms have been worked out in the petroleum industry relating ideal flow to actual flow; there is a need for similar studies in water well hydraulics.

Conclusions

Because of the demonstrated economic importance of water well stimulation, ground water hydrologists should be encouraged to undertake comprehensive theoretical studies of the hydraulic laws involved. Much can be learned by translating to water well conditions the already advanced developments in the petroleum industry. Ground water engineers using such studies should undertake active research and development in the direction of adapting existing petroleum industry techniques to water well conditions and of developing new techniques which are permitted or demanded by water well conditions.

Acknowledgment

This paper constitutes the last of the presently planned series resulting from the water well stimulation survey which has been conducted over more than 3 years. All of the work has been freely published and twelve talks have been presented at professional meetings in as many states. The author has found the opportunity to meet and discuss the subject with innumerable hydrologists, engineers, drillers, and other members of the ground water fraternity most gratifying. The author wishes to express his gratitude to the Halliburton Co., for financial support and professional assistance, and to Jesse Cabrera and Lee McDougall for their able assistance.

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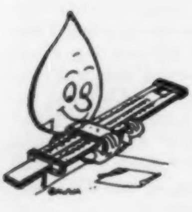
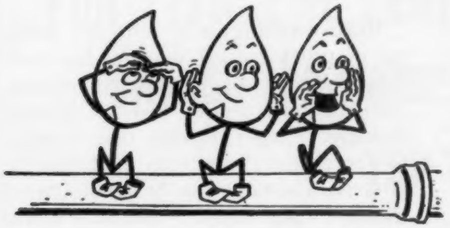




Percolation and Runoff

Water Wonderland, as Michigan calls itself, is going to be more wonderful than ever next Jun. 4–9, when 3,500 water wonders invade its principal city for AWWA's 81st Annual Conference. The program and activities of that conference have all been described to you before, the forms to make your reservation in one of the ten official hotels have been mailed to you. We hope you have already arranged to become one of the wonders, but, if you haven't, it's still not too late. Detroit has loads of room, and Cobo Hall will have loads of attractions—you'll not want to miss Water Works Week in Wonderland!

Water Wertz Week, we might say, for President Caesar will be both kicking off and presiding over the whole show. Caesar invites you. Don't be a Brute!

Speaking of Senator Kerr, by the way—and he will be in Detroit to help Caesar get the conference off to a splashing start on Monday morning, Jun. 5—reminds us to take further note of his report on national water resources. When we printed its summary as the lead article of our April issue, we didn't realize that we would be boosting a best seller. But, with 5,000 copies distributed in its first month and 5,000 more requests on hand, total distribution is being estimated at 20,000 copies, ten times that of the average Senate committee report and "by far one of the most popular in recent years," according to the Government Printing Office. All of which will, we hope, prove to certain skeptical editors that water, like sex, has fundamental appeal. Of course, Kinsey wasn't a Senator.

Foam, which was invented in Germany, is now about to be outlawed there—at least in western there. Lest you start tearing up your passport, though, we should hurry to explain that the suds involved are only those on our liquid, not theirs! Thus, the bill recently introduced into the Bundestag by no less than 50 members of that body has to do with taking the head off only water. According, in fact, to a "pouch" from the American Embassy in Bonn, the bill:

. . . would make it unlawful to manufacture and/or distribute or use certain detergents and/or detergent compositions containing such surface-active compounds as addends [sic] to washing, laundering, or cleaning compositions or products, if

(*Continued on page 44 P&R*)

(*Continued from page 43 P&R*)

such substances do not meet prescribed standards with respect to either their biodegradability or decomposition in water. Only permissible for use as synthetic detergents would be substances that can be subjected to biological degradation, in water purification plants, in natural waters, and/or in soil. Furthermore, the proposed bill would allow use only of those synthetic detergents, the products of whose biological degradation and/or decomposition do not produce harmful effects on human, animal, or marine life, or bring about development in potable waters of objectionable physical characteristics.

It has been proposed that the legislation go into effect on a transitional basis on Oct. 1, 1961, with the establishment of minimum standards for products eventually to be prohibited, the idea being to allow manufacturers and formulators of detergents to adapt their processes to the new requirements. Actually, the scoop is that at least one of the big chemical firms in West Germany is prepared to place on the market a detergent which will meet the requirements of the proposed legislation and that others are already working hard on biodegradables. In the United States, too, we understand, most hush-hushedly, great progress is being made toward "degradation." Perhaps here, too, there ought to be a law against abstergents spelled "ABStergents."

In Vest Chermany, uv gourse, it is rumored that the brau hauses forced the issue, because they were afraid of the heady competition.

Living with penguins in the Antarctic to discover how they separate and excrete salt from the water they drink is a Duke University biologist. We trust that he took his tuxedo with him.

Brainwashing, a hitherto dry process of psychological suasion, has suddenly become a water works matter, with the indication by Swedish Neurobiologist Holger Hyden that thought can be chemically affected and that the effective chemical can be administered through water supply. Actually it was not to start a brain laundry, but to discuss his theory of the chemistry of thought with a group of eminent scientists in San Francisco that Dr. Hyden came to this country last February. The basic hypothesis involved in his theory is that the higher brain functions of memory and reasoning are achieved by the way the neurons of the brain alter the protein they form. As described in *Time* magazine:

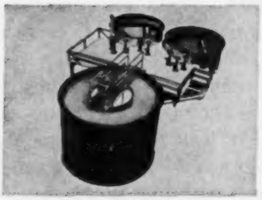
> Each neuron contains millions of molecules of riboneucleic acid (RNA). Each of these molecules is chemically keyed by the arrangement of its internal building blocks. These molecules dictate, in accordance with their keys, the nature of the proteins that the neuron forms, in cooperation with the glial cells. The modified proteins are the chemical representations of thoughts. Memory is thus the imprinting of a code on RNA molecules in millions of cells, like punch holes in a set of IBM cards.

From this base, Dr. Hyden proceeded with his experiments and discovered that small doses of a new synthetic chemical called tricyanoaminopropene caused drastic changes in neuronal RNA and proteins in animals and—according to preliminary studies—in man, and he was able to report that "there is now evidence to prove that RNA and enzyme changes are followed by an increased suggestibility in man."

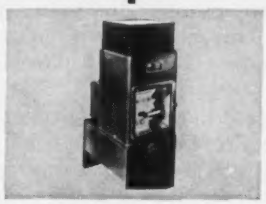
Indicating that such substances could be useful in modifying the behavior of

(*Continued on page 46 P&R*)

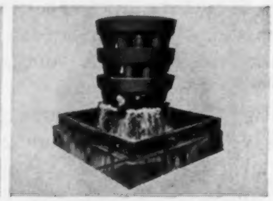
FOR EFFICIENT PERFORMANCE...
choose the water treating equipment you need from the complete INFILCO line



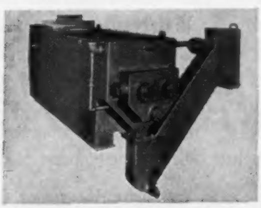
ACCELAPAK® treating plant, complete in a single package for the treatment of surface or well waters in capacities from 15 to 350 g.p.m. Ideal for small communities, industrial plants or institutions.
Bulletin 1870-A.



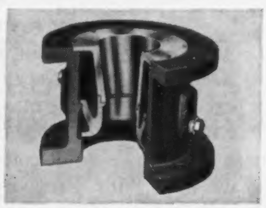
Dry Feeders . . . Type E provide automatic proportional or constant rate feeding. The feeder with linear feed adjustment throughout capacity range of feeder; extrusion type, simultaneous rocking and reciprocal motion of feed pan.
Bulletin 215-D.



MULTICONE Aerators . . . Low head requirements. Efficient, compact, rugged. Air induction, cascade type. Primary, secondary, and discharge cone assemblies mounted one above the other upon a central inlet pipe.
Bulletin 101-A.



VISCOMATIC® slaker . . . Either high calcium or poor grades of lime are slaked in the form of a paste which is then diluted and fed as lime slurry. High paste temperature results in complete slaking without the need for hot water. Arranged for continuous grit removal.
Bulletin 255-A.



TWIN THROAT Venturi . . . A specially designed venturi tube providing highest accuracy and shortest laying length and the lowest head loss for any given differential. Can be used for metering water, sewage, air or other gases or fluids.
Bulletin 1021.

See your consulting engineer if you are planning any installation. His services are essential for the design of your plant and the selection of equipment that best meets your requirements.

These are only a few of the products for water treatment in the complete INFILCO line which includes equipment to meet your every need.

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Subsidiary of General American Transportation Corporation

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Field offices throughout the United States and in other countries

GENERAL AMERICAN

6011

(Continued from page 44 P&R)

neurotic or otherwise mentally disturbed people, he also theorized that "a police state government could add such substances to tap water and brainwash the whole population at once." Of course, he pointed out that chemical countermeasures to keep the brain unwashed were "not difficult to imagine." And, of course, our own chemical friends have already imagined and have been applying countermeasures as part of their regular treatment procedures for some time now. But we will admit to a momentary thought or two that tricyanominopropene might really be the key to gaining that long sought public support. And it wasn't so much our conscience, or even the certain "I-told-you-so's" of our antifluoridationist friends, that made them merely momentary as the realization that even suggestible customers aren't enough. We'll not settle for anything short of convinced ones—washed or unwashed!

Speaking of words, though, we discovered "aqueous humor" just the other day and found that it is not at all what we strive for in these pages month after month, but what we look through at them—"a limpid fluid," that is, "between the crystalline lens and the cornea of the eye." At least the fact that it is almost 100 per cent water makes us feel a little happier at the prospect of never being able to create it.

Uel Stephens has retired as director of the Fort Worth (Tex.) water department, to serve as an advisor on development of the area's water and sewage facilities. His successor is W. Ralph Hardy, assistant director since 1955.

Samuel B. Morse, consultant and formerly chief engineer of the Los Angeles Dept. of Water & Power, has been appointed to the California Water Commission by Governor Edmund G. Brown. An Honorary Member of AWWA, he served as president in 1944.

Color is one of those characteristics that water utilities have always considered objectionable in their product. Is it possible they've been wrong?

Just last month we read about the introduction of color in the water softener field. It was the softener itself that was colored, of course, but just the idea that painting a product in pastels will increase its sales, despite a price tag running from $295 to $495, certainly makes us wonder.

And down at West Palm Beach last month, the water department became color conscious, too, and reported significant savings in lost tools as a result. There the color—a bright orange—was used to make the tools show up in the grass or on the ground and prevent their being left behind, but still.

And consider what the "blue" did for Rinso.

Of course, water is a product to be consumed, but, then, who objects to the color of bourbon? Or butter? Or oranges? So why shouldn't water be a bright blue, for instance, to match the color of Willing Water's face?

E. H. Aldrich has resigned as chief engineer of the American Water Works Service Co., Philadelphia, but will continue his association with the firm as a vice-president and engineering consultant. Thomas C. Earl has been named to the position of chief engineer.

(Continued on page 48 P&R)

(*Continued from page 46 P&R*)

Mother Goose's age may at least have been suggested by the recent discovery in West Berlin of an 1,800-year-old well with the skeletons of a number of mice at the bottom of it. "Ding, dong, dell . . ." was our immediate response, but then the same archeologists who labeled the well 1,800 yr old indicated that the skeletons dated from the second century B.C. Unless, of course, nine lives went a lot further in those days. Even so, though, we don't quite dig it.

'Disinsection' was a word that caused us pause the other day when we encountered it in a report of the WHO Expert Committee on Insecticides, but, of course, it is a perfectly understandable term for "the operation in which measures are taken to kill the insects present in aircraft or ships." Extending the thought we rather presumed that the Committee on Rodenticides would lean toward "disrodention," but we should like to urge consideration of "deratification" as much more pronounceable and specific. Bringing the thought a step—and, we promise, only one step—closer to home, we sought to apply it to terminology in the water works field, and specifically to "the operation in which measures are taken to remove odors present in water supplies." Reeschewing anything as simple as "deodorizing," we considered "disstinktion" briefly and even "desmellification," but we rather think that, WHO nomenclatural procedures to the contrary notwithstanding, we still prefer "pewrification."

(*Continued on page 50 P&R*)

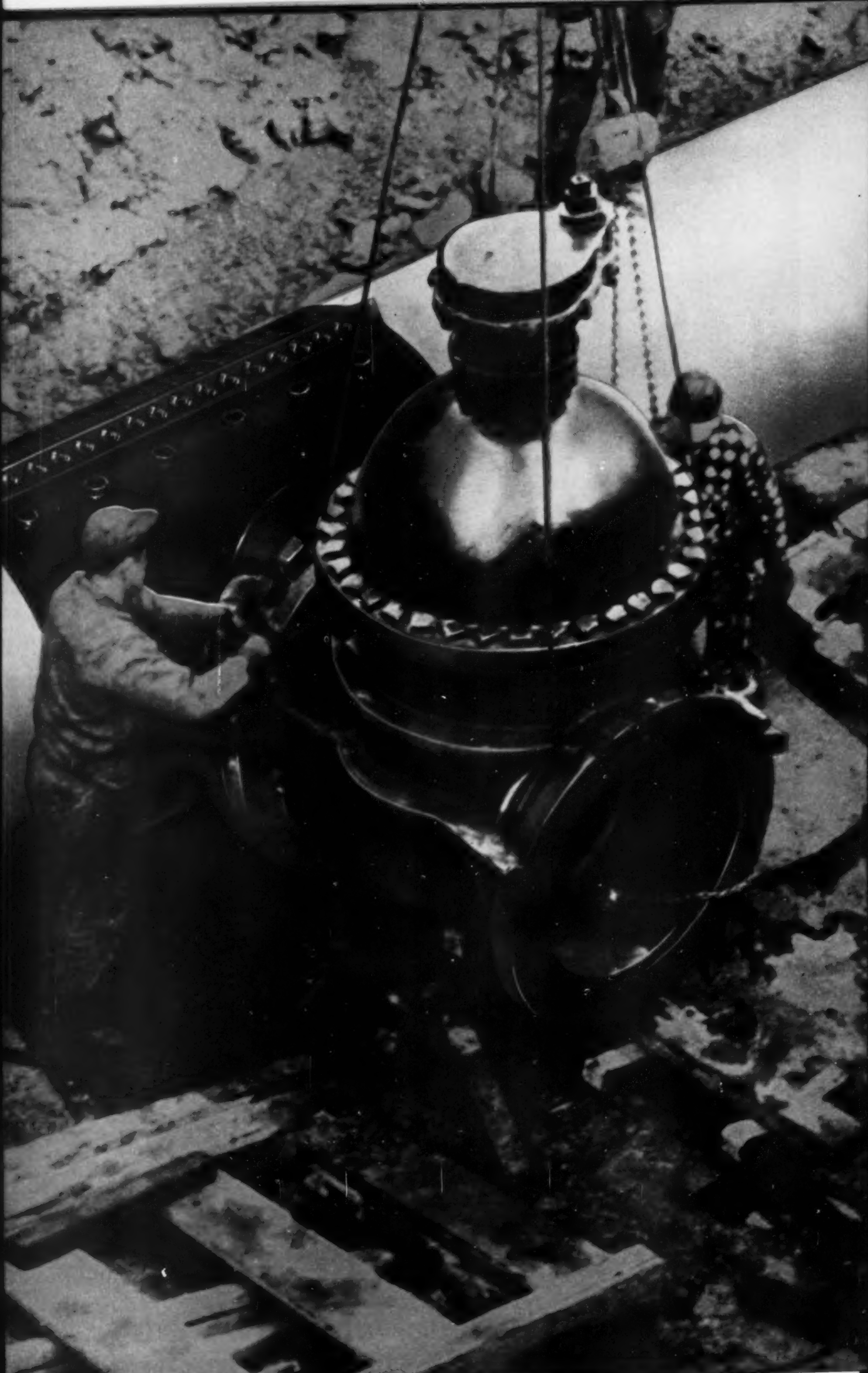
(*Continued from page 48 P&R*)

'Allons enfants de la patrie!' is the cry once more in France—at least in Paris—at least on the street corners—for the Vespasiennes are disappearing fast and, in Paris, when you've gotta *allons*, you've gotta *allons*. The Vespasiennes, lest your Parisian be rusty, are those circular, sheet-metal, knee-low outhouses that once made almost every corner in the city a comfort station. At the 1,200 level in 1930, these corner conveniences have now been reduced to 350, and men of spirit—at least men of spirits—are beginning to protest. So loud has the cry become that the Municipal Council is once more embroiled in a debate concerning the rights of man—*les droits sanitaires,* that is. And the students, it is rumored, are threatening to resurrect the street corner urns of the Roman Emperor Vespasian that led to and gave name to the currently retreating retreats. After all, if the problem is merely economic, it would be simple to install turnstiles.

H. Edward Keating has been appointed director and executive vice-president of the New Rochelle (N.Y.) Water Co., to take charge of the company's operations. Formerly he was general manager of Consumers Water Co., Coral Gables, Fla., also a subsidiary of General Waterworks Corp.

In the pig's sty, running water, yet. Individual shower heads dispensing water at a pig's push on a pedal is the latest innovation in the pig's paradise that Gunnar Nilsen, Norway's leading meat packer, has created to prove that pampered pigs produce the premier pork. Other features of this hog heaven are individual apartments for each of the 3,500 inhabitants, with sweet swine music piped in. Luxury is for wallowing in, too.

(*Continued on page 54 P&R*)



a snap
to tap...
concrete
pressure
pipe

**LARGE
OR SMALL**

Thousands upon thousands of permanent pressure taps made in concrete pressure pipe demonstrate conclusively the ease and efficiency with which this type of pipe may be tapped for small service connections or larger outlets.

Taps from ⅝" to 42" have been made under pressure in pipes varying in diameter from 10" to 150", without damage to the pipe's structure or interruption of service. Tapping is accomplished with conventional and commercially available equipment.

The fine safety record of this tapping operation and the equally high safety record of the pipe itself, makes CONCRETE PRESSURE PIPE the ideal medium for distribution mains, particularly in congested areas where pipe failure is synonymous with disaster.

You can always depend on CONCRETE PRESSURE PIPE.

WATER FOR GENERATIONS TO COME

Concrete PRESSURE Pipe

AMERICAN CONCRETE PRESSURE PIPE ASSOCIATION
228 North LaSalle Street, Chicago 1, Illinois

(Continued from page 50 P&R)

Lock Joint Pipe Co., East Orange, N.J., has acquired Electro Chemical Engineering & Mfg. Co., of Emmaus, Pa., in an exchange of stock. The new subsidiary specializes in chemical resistant paints, linings, and coatings. The present management, headed by C. R. Payne, president and founder, will be retained.

Free flowing wells are being offerred in Jacksonville, Fla., as a premium with the purchase of heat pumps. All a homeowner has to do is order a "water type heat pump system—the most economical way to heat and cool his home" and the supplier will drill his well free. With our captive market, it probably would serve no purpose to advertise free meters with every new service, but we might make an impression offering free water to fight any fire!

Carl H. Simon has been elected to the board of directors of ASA for a three-year term. As executive vice-president and general manager of Darling Valve & Mfg. Co., he will represent the valve and fittings industry on the board.

Rutgers University will name its new $3,500,000 biology building Nelson Biology Laboratories, in honor of Thurlow C. Nelson, who died Sep. 12, 1960, and his father, Julius Nelson, who also served the university for many years. The structure is expected to be completed by September.

(Continued on page 59 P&R)

This Month Years Ago

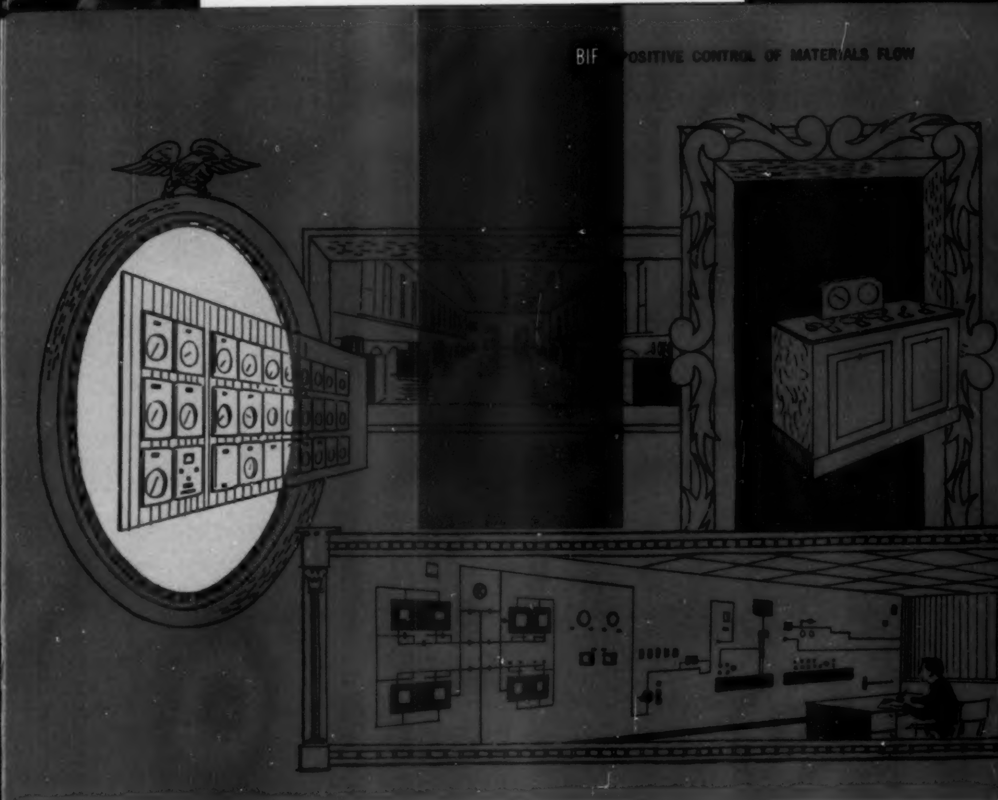
May 1861—During a six-month period, according to his report to the Chief Engineer of the Brooklyn Water Works, John H. Rhodes "inspected and proved 6,432 pipes, consisting of 3,369 6-in., 2,230 8-in., 423 20-in., and 250 30-in., rejecting, upon inspection under proof, 158 6-in., 98 8-in., 58 20-in., and 14 30-in. A very considerable number, in addition, were rejected without subjecting them to the proof. The above were rejected from one or more of the following causes, viz: blisters, sand holes, shrinkage cracks, air cells, and cold shuts.

The 6-in. and 8-in. pipes were cast in green sand moulds with green sand cores, placed horizontally. The 20-in. and 30-in. pipes were cast vertically with the "hub" end down in "dry sand moulds" and "loam cores."

May 1911—Water tanks located on the roof or external part of buildings in New York City must hereafter be tightly covered or else provided with an extra-fine-mesh screen to prevent the access of mosquitoes to stored water. . . .

In his paper on "Bleaching Powder as an Agent in the Purification of Water," Nicholas S. Hill cautions that "The use of hypochlorites can hardly be considered as a substitute for filtration." . . .

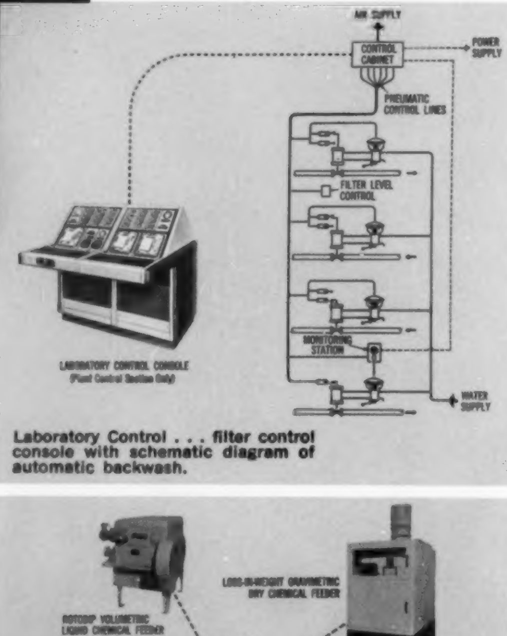
"Before leaving the topic of interpretation of analyses," said Professor W. P. Mason, "it is right to add that we cannot but deplore the fact that not a few opinions are still given without sufficient knowledge of the conditions surrounding the source of supply; that is, without the 'sanitary survey.' Is not the risk of venturing an opinion on laboratory data alone pretty much the same as that assumed by the physician who formulates a diagnosis and writes a prescription without seeing the patient?"



B-I-F Laboratory Control

B-I-F LABORATORY

The entire filtration and treatment process under the direct control of only one qualified man . . . the plant chemist or chief operator!



Laboratory Control . . . filter control console with schematic diagram of automatic backwash.

Laboratory Control. . .typical arrangements with chemical feeders paced by flow.

FILTRATION PROCESS

More Efficient Filtration — Automatic backwash control increases reliability of operation . . . permits initiation of manual or automatic backwash program from laboratory console . . . assures high quality effluent. Operations recorder stores all information relative to filter performance in concise, visual form for future reference, eliminating multiple chart changing and storage problems . . . monitors all operations and instantly signals any terminal or abnormal condition.

Saves Space and Taxpayers' Dollars — Centralized control eliminates initial cost and maintenance of the filter housing structure, of individual filter operating stations and allied instrumentation. System reduces damage to beds and resulting downtime . . . assures more productive man-hours.

CHEMICAL TREATMENT

Key-Man Supervision and Control — Chemist or plant operator . . . from central console or laboratory . . . easily controls quantity of filtered water and exact chemical dosages for treatment. Monitoring lights or alarms instantly advise of filter conditions . . . over or under feeding of chemicals, empty hoppers, etc. . . . enabling key-man to make immediate, corrective adjustments. Integrating totalizers provide accurate accounting of quantity of water treated and exact amount of chemicals fed during operating period.

More Effective Operation at Lower Cost — Chemical feeders are remotely located for straight-line process flow (see diagram) which protects floc, improves settling and provides longer filter runs. Remote location of feeders reduces initial plant cost by eliminating need for expensive housing structures . . . reduces maintenance cost by removing chemical dust problem from office and laboratory.

CONTROL

IMPROVED PLANT OPERATION!
INCREASED RELIABILITY!
LOWER INITIAL PLANT COST!
REDUCED OPERATING COST!

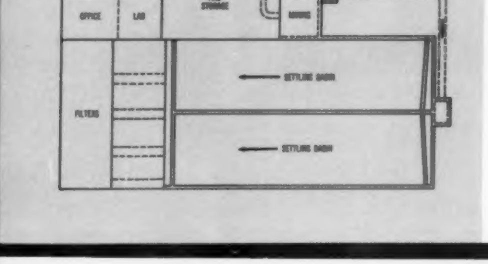
- Provides instant fingertip control over plant throughput, chemical additions, and filter backwash . . . from a single console in laboratory.
- Simplifies and improves process supervision . . . releases manpower for more productive assignments.
- Assures filtration efficiency — centralized backwash control automatically initiates washing . . . eliminates over or under washing and upset filter beds.
- Reduces overall plant construction costs 15% to 20% by eliminating structures over filters.

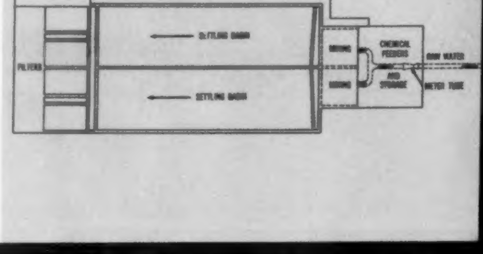
Typical arrangement of water filtration plant with Laboratory Control.

FACILITIES ARRANGEMENTS

CONVENTIONAL DESIGN: requires costly structures to protect operators from the weather and to house filters and individual filter operating tables with associated recording-controlling instruments.

LABORATORY CONTROL: all operating controls centralized in **one** compact console in the laboratory. The plant is designed for streamlined flow and maximum process efficiency at minimum structural cost.





Laboratory Control . . . typical arrangements with chemical feeders paced by flow.

(*Continued from page 54 P&R*)

As a matter of fact

1,200 bgd is the rainfall runoff to streams, potentially available for use. Of this amount, it may ultimately be economically feasible to develop 635–650 bgd. Approximately 230 bgd is now reported used in the US for all purposes, but, of this, only about 72 bgd is actually "consumed." By the year 2000, it is estimated that the net daily loss of available water by "consumption" will be at the level of 117 bgd,—that is 18 per cent of estimated daily yield. No hoax, but Hoak's—Richard D. Hoak's, of Mellon Institute, Pittsburgh—are these comforting data.

97 per cent of the human embryo and almost 100 per cent of a cucumber is water. A newborn baby, though, is somewhat easier to distinguish, being only 77 per cent water (on the inside, that is). And the adult, despite a growing tendency toward a cucumbersome exterior, is no more than a desiccated 67 per cent water. Little wonder so many adults drink!

3,000,000,000 people—the entire population of the world, that is—could be fed with the algae covering an area the size of Rhode Island. So, who's hungry?

471.68 in. per year is the average rainfall on Mt. Waialeale, Hawaii, making it the wettest place in the world, although barely a cloudburst or two ahead of Cherrapunji, India, which pours in at 450 in. per year. Of course, Cherrapunji still holds the 12-month record of 1,041.78 in., recorded from August 1860 to July 1861. In the continental United States, Wynoochee Oxbow, Wash., holds the record at a merely damp average of 150.73 in. per year. Driest place in the States is Greenland Ranch in California's Death Valley, averaging 1.78 in. per year, although nearby Bagdad, in the Mojave Desert, holds the record for rainlessness, having had 767 days of drought in a row from Oct. 3, 1912 to Nov. 8, 1914. If you really want to worry where your next drop is coming from, though, head for the port of Arica in northern Chile, averaging 0.02 in. per year. These, we understand, are holiday spots for weather men.

40,000,000 tons of snow was dropped on New York City in the Feb. 4 snowstorm. Converting this snow into rain by the application of heat, as suggested to the weather man, was calculated to require the heat of 2,400,000 tons of high explosives. And probably a good idea, too. Break up the Yankees, we say!

2,500 ft of depth into the earth is estimated to contain as much water as has fallen in rain for the last 150 yr, according to the *Encyclopedia Britannica*. Well, well, we say!

(*Continued on page 60 P&R*)

(Continued from page 59 P&R)

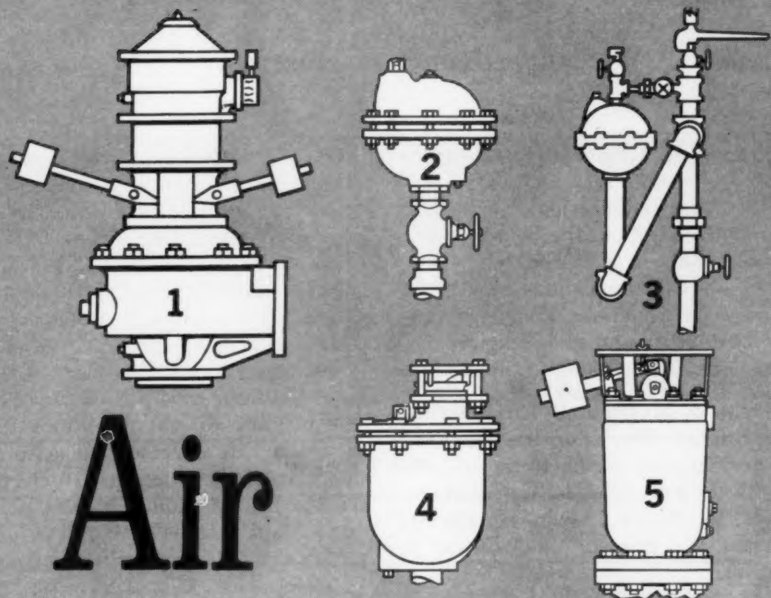
Reeves Newsom has relinquished the post of village manager for Scarsdale, N.Y., to become administrative consultant to the village until his retirement on Sep. 1. A former president of AWWA (1939), he is an Honorary Member of the Association. His successor is Lowell J. Tooley, formerly assistant village manager. Gerald Riso is the new assistant village manager.

General Electric Co. announces that it has completed tests on a new distillation process for desalinization. The announcement came after more than 1,000 hours of tests, conducted under contract with the Navy and the Office of Saline Water. Features of the new system include an assembly of revolving blades, operating much like automobile windshield wipers, and the vaporization of water without its either boiling or bubbling.

Roy Ruggles has retired as chief engineer of construction for the Atlanta (Ga.) Water Works. His successor is C. W. Cline, an employee of the engineering department for 14 years.

Harry Hayes has retired as senior sanitary engineer for the Los Angeles Department of Water & Power. A member of AWWA since 1933, he was awarded the Goodell Prize in 1937. His position has been filled by Joseph M. Sanchis, formerly a sanitary engineer. His post in the engineering section has been filled by William K. Weight.

(Continued on page 62 P&R)



Air

How to protect your pipeline from too much or too little of it.

1. Prevents water hammer: Type CCAV Controlled Closing Air Valve protects against damaging effects of surge and water hammer. Combines functions of an air inlet valve (vacuum breaker) and a controlled closing unit (to prevent sudden water stoppage and subsequent water hammer). 4" and 6" sizes. Capacities from 575 to 5980 gpm. Send for Bulletin 1225.

2. Removes excess air: Type AGFD Automatic Air Release Valve prevents stoppages due to air-lock at high points in line. Has large discharge capacity, excess power to insure opening of the valve against high internal pressure. Can be equipped to hold vacuum, preventing re-entry of air into pipeline through valve. Furnished with 2", 1½" or 1" inlet diameter. Standard valve operates to 250 psig—special to 300 psig. For details, send for Bulletin 1206.

3. Protects sewage pipelines: Type "B" Air Release Valve, special for lines carrying sewage or sludge, removes entrained air and gases. Special trap catches sludge, prevents fouling of air release valve. Relatively simple back-flushing cleans out this trap, maintains top efficiency and protection. Valve itself is same as Type AGFD. Details are in Bulletin 1206.

4. Provides three functions: Type AV Air Release and Air Inlet Valve performs three operations, combines great protection and single-unit economy: (1) Automatically releases accumulated air, (2) admits air to break vacuum, and (3) vents pipeline to permit escape of air when filling system with water. Standard units operate to 150 psi. For full details, send for Bulletin 1205.

5. Breaks vacuums: Type VAC Air Inlet Valve solves two serious pipeline problems: possible collapse of pipelines due to formation of vacuums—and stoppage of flow, caused by air binding when lines are being filled. Standard units have 4" to 10" inlet diameters, can be assembled in groups to do the work of one large, expensive valve. For 16 pages of detailed information, send for Bulletin 1202.

SIMPLEX
VALVE AND METER COMPANY
a division of PFAUDLER PERMUTIT INC.
Lancaster, Pennsylvania

(*Continued from page 60 P&R*)

Thomas R. Glenn Jr. has been appointed executive secretary of American Sanitary Engineering Intersociety Board. In addition, the board's office has been transferred to Highland Park, N.J. All communications should be addressed to Box 143. The new secretary is director and chief engineer of the Interstate Sanitation Commission.

Burns & McDonnell Engineering Co., Kansas City, Mo., has admitted five former staff members to partnership in the firm: Leo L. Cunningham, Jasper W. Meals, Alwin H. Rector, William W. Rumans, and Edwin J. Runyan.

Burgess-Manning Co., Libertyville, Ill., has sold its Penn Instruments Div. to Penn Meter Co., of Philadelphia, a newly formed corporation. W. E. Williams is president and sales manager.

Kenneth W. Brown, partner of Brown & Caldwell, San Francisco, Calif., died Jan. 2, 1961, in San Francisco. He received both his A.B. and Ch.E. degrees from Stanford University, and worked as a sanitary engineer for various firms from 1925 until 1944, when he entered private practice. A member of AWWA since 1927, he was a Life Member.

John B. Harrington, formerly state sanitary engineer for West Virginia, died at Beckley, W.Va., on Mar 6, 1961, at the age of 62. He served with the state health department from 1925 to 1949. For many years he was secretary of the old West Virginia Conference on Water Purification, which was the predecessor of the present West Virginia Section of AWWA. A member of the Association since 1938, he served as director in 1940–43 and received the Fuller Award in 1941.

H. F. Wiedeman, president of Wiedeman & Singleton, Atlanta, Ga., died April 6, 1961, in Atlanta. A graduate of Rensselear Polytechnic Institute, he served as a captain in World War I. After the war he went to Atlanta, where he joined the firm of Norcross & Co., the predecessor to Wiedeman & Singleton, which partnership was formed in 1927.

A member of AWWA since 1925, he was a Life Member and a former chairman of the Southeastern Section. He was also a member of ASCE.

Employment Information

Classified ads will be accepted only for "Positions Available" or "Position Wanted." Rate: $1.50 per line (minimum $5.00), payable before publication. Deadline for ad copy: first of month prior to month of publication desired. To place ad, obtain "Classified Ad Authorization Form" from: Classified Ad Dept., Journal American Water Works Assn., 2 Park Ave., New York 16, N.Y.

Positions Available

CITY ENGINEER

Applications are invited for the post of City Engineer from persons of considerable experience of municipal and water and sewerage utility operations, maintenance, and construction. Starting salary commensurate with experience and qualifications. Pension, hospital, and insurance benefits available. Applications marked "Confidential" addressed to City Manager, City Hall, Corner Brook, Nfld., will be treated in confidence.

TECHNICAL SALES AND SERVICE WATER TREATMENT

Unusual opportunity for graduate chemist or chemical engineer with at least 5 years experience in water field. Must be free to travel and thoroughly familiar with municipal and/or industrial water treating systems. Salary open. Send resume of background now for interview at Detroit AWWA Convention, or after June 15th, to Mr. S. Bruce Humphrey, Director of Marketing, Carus Chemical Company, Inc., 1379 Eighth Street, LaSalle, Illinois.

Service Lines

Rapid sand filter controls are the subject of a new 4-page, illustrated brochure. Bulletin No. 450 may be obtained from Bailey Meter Co., 1050 Ivanhoe Rd., Cleveland, Ohio.

Pumps, both centrifugal and turbine, are illustrated and briefly described in a 4-page bulletin. Copies of the material titled "Pumps" are available from Aurora Pump Div., The New York Air Brake Co., Aurora, Ill.

Conversion factors may be obtained quickly by the use of a free wall chart, which may be obtained by writing Precision Equipment Co., 4411E Ravenswood Ave., Chicago 40, Ill.

Protective coatings for pipeline systems are the subject of an illustrated, 10-page bulletin that features a color-coded selector as an aid in selecting the correct coating system for specific field conditions. Bulletin T-204 may be obtained from the Tar Products Div., Koppers Co., Inc., Pittsburgh 19, Pa.

Asbestos-cement pipe is described, with tabular data and photographs, in a 8-page brochure, available by requesting TR-160A from Johns-Manville, 22 E. 40th St., New York 16, N.Y.

Gate valves that have been recently redesigned are described and illustrated in a new 4-page, illustrated bulletin. Copies are available by asking for Bulletin 301 from DeZurik Corp., Sartell, Minn.

Correspondence

AWWA.4

To the Editor:

I would like to present to you an idea that has interested me for some time. There are many people of the world who need sanitary water supplies. I would like to see the AWWA select one town a year from the needy areas and build a water system through member contributions. I would be pleased to see the people of the American water industry show compassion for their fellow man in this manner. I hope some day that individual American cities will sponsor a water system in areas of great sanitary need.

JAMES P. DOVEL

Birmingham, Ala., Feb. 16, 1961

* * * * *

Fidel Fodel

To the Editor:

Your article "Remember the Main" (January P&R, p. 38) brings back memories of some twenty years ago when the writer supervised the construction of the Guantanamo Bay Naval Base water treatment plant. My recollection makes me think the Yeteras River mentioned in the article is actually the Yateras River.

Those who might be further interested in the water supply problems of the station may refer to the March 1961 issue of the *National Geographic.*

WATSON ELLIS

Palo Alto, Calif.; Feb. 27, 1961

* * *

*Reader Ellis is correct. Fidel has not yet changed the spelling.—*ED.

Professional Services

Professional Services

Professional Services

Professional Services

Condensation

Key: In the reference to the publication in which the abstracted article appears, 39:473 (May '47) indicates volume 39, page 473, issue dated May 1947. If the publication is paged by the issue, 39:5:1 (May '47) indicates volume 39, number 5, page 1, issue dated May 1947. Abbreviations following an abstract indicate that it was taken, by permission, from one of the following periodicals: *BH—Bulletin of Hygiene (Great Britain); CA—Chemical Abstracts; Corr.—Corrosion; IM—Institute of Metals (Great Britain); NSA—Nuclear Science Abstracts; PHEA—Public Health Engineering Abstracts; SIW—Sewage and Industrial Wastes; WPA—Water Pollution Abstracts (Great Britain).*

WELLS AND GROUND WATER

Some Problems Connected With the Theory of the Origin of the Chemical Composition of Underground Waters. S. I. Rybakov. *Trudy Lab. Gidrogeol. Problem im. F. P. Savarenskogo, Akad. Nauk S.S.S.R.,* 16:74 ('58). The importance of studying the isotopes present in underground waters is stressed. The properties of these isotopes are not limited to their familiar phys. and chem. characteristics. For example, it is well known that heavy waters are poisonous to living organisms; nevertheless life is not wiped out. Thus, it appears that other, not yet identified, isotopes of H_2O components not only neutralize the harmful effects of the destructive isotopes, but stimulate the evolution of org. forms. The living organisms that inhabit the earth play an outstanding role in the sepn. of isotopes of C, S, O, and H. In rocks, water, and gases of the earth, as one isotope disappears another forms.—*CA*

Geology and Ground Water Resources of the Rawlins Area, Carbon County, Wyoming. D. W. Berry. *USGS Wtr. Supply Papers,* 1958 ('60). Springs and wells, some under artesian pressure, yield water from Madison limestone, Tensleep sandstone, Sundance formation, Cloverly formation, Frontier formation, and Miocene and Pliocene rocks. The water is mostly suitable for domestic and stock use, and more can be obtained than is now being used. One well from the lower Frontier formation was high in F content (7 ppm).—*CA*

Characteristic Hydrochemistry of the Underground Water in Loess Sediments of the Dnieper Basin. E. V. Ishkova. *Nauch. Zapiski Dnepropetrovsk. Gosudarst. Univ., Sbornik Rabot Nauch.-Issledovatel'. Inst. Geol.* (Moscow), 58:107 ('57). The chem. compn. of underground water shows its high mineralization after its passage through the sediments above the water horizon. Loess, a mixt. of loess and clay, and sandy clays with gypsum are located in watersheds along which atm. pptn. gives rise to a supply of underground water; some minerals are dissolved in sediments and others are pptd. Although a complex mixt. of loess and clay contains an avg of 9% of CaO and 3% of $MgO\text{-}Na_2O$, in ratio 3:1, this ratio is reversed to 1:4 in underground water contg. $\geq$40% $MgO\text{-}Na_2O$, $\leq$10% CaO, with $\leq$43% SO_4^{--} of dry ppt. (max. 8.7 and min 1.1 g/l) in H_2O. The concn. of SO_4^{--} to near 5,000 mg/l, as in this sample, makes water dangerous to the concrete installations as gypsum may be recrystd. in concrete pores. The presence of NH_4^+ $\leq$1.5, NO_2^- $\leq$0.4, and NO_3^- $\leq$26.8 mg/l is an indication of decompd. org. matter in underground water. The pH of the water is 7.0–7.5. Its free CO_2 varies from 8.24 to 25.28 mg/l; active CO_2 is usually absent. Hardness makes water unsuitable for industrial use. Some water samples show salinity and carbonization, but most samples show sulfates. Chem. reactions in water are replacement of Ca^{++} with Na^+, then of Na^+ with Mg^{++}, and pptn. of $CaCO_3$ and $CaSO_4$ by combined action of $Mg^{++}\text{-}Na^+\text{-}K^+$.—*CA*

Ground Water Flow in the Netherlands Coastal Dunes. D. K. Todd & E. Huisman. *Proc. ASCE,* 85:63 ('59). A mathematical anal. is given of the ground water conditions in the coastal dunes which provide a water supply for Amsterdam, the Netherlands. The problem is treated two dimensionally, with a lens of fresh water above, and a pocket of fresh water below, a layer of clay; the fresh-water pocket has lateral tongues which extend beyond the fresh water lens. The whole area is underlain with salt

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water. From the equations developed, it is possible to estimate the movements and boundaries of the fresh water.—*WPA*

Ground Water Utilization, Suffolk County, L.I., New York. J. F. Hoffman. *Proc. ASCE,* 85:25 ('59). The occurrence, movement, and quality of ground water in Suffolk County, Long Island, N.Y., are described, and the use of ground water for domestic, industrial, and agricultural purposes is reviewed. It is est. that in 1955 more than 24,000 mil gal of ground water was used; this is about 7% of the avg ground water recharge in the area. Continued increase in the amt. of ground water used may cause problems resulting from encroachment of sea water, lowering of the water table, contmn. with waste waters, and rise of temp. Possible methods of overcoming these problems and controlling ground water development are indicated.—*WPA*

Occurrence of Ground Water of Low Hardness and of High Chloride Content in Lyon County, Minn. H. G. Rodis & R. Schneider. *USGS Circ.* 423 ('60). Soft (<70 ppm and moderately hard (70–120 ppm) H_2O occurs in an area of about 130 sq mi, including approx. 20 sq mi where only soft H_2O is found. The Cl cont. ranges from 50 to 500 ppm except for 50 sq mi in the north-central area where the range is 500–2,000 ppm.—*CA*

Variations in Mineral Content of Some Ground Waters. S. Buchan. *Proc. Soc. Water Treatment Exam.,* 7:11 ('58). The author attempts to explain the compn. of ground waters on the basis of knowledge of the geol. strata through which they had passed. Sampling of percolated H_2O at various depths shows a variation in compn. Hardness, alky., and salinity may increase to a max. and then decrease as the H_2O passes through different strata. Total rainfall, sol. salts on the surface, dissolved CO_2, farming practices, aquifer drawdown, and ground geology have an effect on the mineral cont. of the ground waters. Chem. analyses are given for 47 samples.—*CA*

Synthetic Detergents in Well Water. J. Deluty. *Pub. Health Repts.,* 75:75 ('60). A total of 25 wells in the Quaker Hill subdivision of Portsmouth, R.I., were analyzed, and all but one contained detergents ranging from 0.15 to 5.0 ppm. The detergent level of those that did not show a soap foam on shaking ranged from 0.15 to 0.4 ppm. Results are tabulated for all 25 wells: depth, sediment, color, free NH_3, albuminoid NH_3, NO_3, NO_2, Cl, detergent, coliforms, and distance from disposal field. The only form of N that tended to be abnormally high for this area was NO_3.—*CA*

Model Approach to a Ground Water Problem. K. R. Wright. *Proc. ASCE,* 84:IR4 ('58). The author describes the use of an electric analogue plotter and a hydraulic model for investigating a ground water problem where a direct field study could not be made. The electric analogue was limited by the necessity of assuming a one-density system, but otherwise it offered good detailed information on the flow patterns. The hydraulic model operated satisfactorily with different density liquids, nonequilibrium conditions were readily studied, and a time scale was introduced making it possible to forecast future events which would be most difficult to obtain by mathematical anal. The results of the two models were close enough for both to be considered reliable.—*WPA*

Geochemical Characteristics of Ground Waters in Kuznetsk Basin and Its Petroleum Prospects. V. G. Glezer. *Materialy po Geol. i. Neftenosnosti Kuznetsk. Basseina, Akad. Nauk S.S.S.R.* ('60), p. 226. Anals. of 400 underground water samples from different parts of the Kuznetsk Basin indicated the presence of 3 hydrodynamic zones (from bottom to the top): (1) a stagnant zone; (2) a zone of restricted water exchange; and (3) a zone of free water exchange. The waters of the stagnant zone are found only in the Barzassk region in the bottom of Upper Devonian and in Middle Devonian. They are of Cl-Ca type and have the highest (in comparison with other waters) mineralization and very low sulfate cont., indicating the reducing character of their environment. The waters of restricted water exchange (Borisov region, Abashev Dome, East and West Nevskaya anticline) are of the $NaHCO_3$ type with mineralization of 37–238 mg/l and all signs of a reducing environment. The waters with increased mineralization are usually in the

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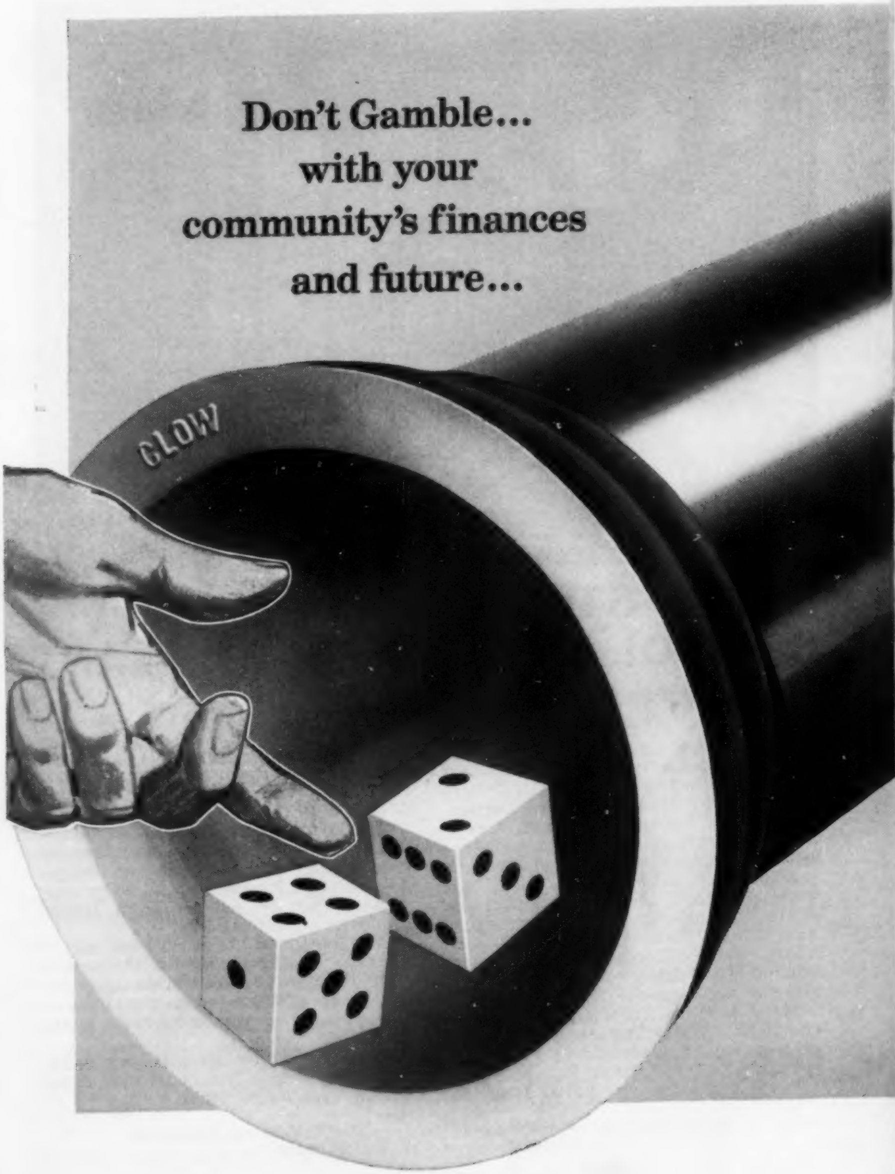
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deeper formations. The waters of free exchange are the most numerous. Their mineralization is not more than 25–30 mg/l and the presence of sulfates and HCO_3^- suggests oxidative conditions of environment. The most favorable hydrochem. symptoms (oil or gas prospects) are in the Barzassk, Borisov, Ermakov, and Zalominsk regions in the West Nevskaya, Ermakov, Borisov, and Abashev structures (domes and anticlines).—*CA*

Soda Formation in Underground Waters. S. S. Chikhlidze. *Trudy Lab. Gidrogeol. Problem im. F. P. Savarenskogo, Akad. Nauk S.S.S.R.*, 16:141 ('58). The alkali carbonates in H_2O can be formed either by the decompn. of silicates contg. Na—e.g., the feldspars—by the action of H_2CO_3, or by cation exchange of $Ca(HCO_3)_2$ dissolved in the H_2O with colloids adsorbed by the complex rock structure. Results of a series of expts. on the production of $NaHCO_3$ in exchange reactions of 150-g samples of various rock materials in a H_2O:mineral ratio of 5:1, in contact for periods varying from 1 day to 9 months; with and without the presence of CO_2, show that the factor governing the process is the length of time of contact; degree of CO_2 satn. of the H_2O is next in importance.—*CA*

Petroleum Products in Soil and Underground Water. M. Knorr. *Water* (The Hague), 41:247, 276 ('57). Petroleum-product content of water increases dangerously. Various sources of oil, tar, C_6H_6, and derivs. in underground water and rivers are related. Ultraviolet spectrophotometric anal. shows the presence of small amts. of hydrocarbons generally considered as insol. in water. Several examples point out how mineral oils infiltrate in different soils and how they pollute even remote sources. C_6H_6 evolution in calcareous, marly, and sandy grounds is thoroughly examd. Drilling is particularly dangerous for water distribution in the neighborhood. Moreover, collecting of petroleum contg. as much as 80% salted water is not rare. The prejudicial actions of petroleum derivs., especially their carcinogenic power, and protection rules are discussed.—*CA*

Studies of Ground Water Flow by Using Radioactive Isotopes: Preliminary Report. G. Knutsson & K. Ljunggren. *Geol. Foren. i Stockholm Forh.*, 81:405 ('59). A description is given of expts. with I^{131}, Cr^{51}, and T (in iodide ion, Cr ethylenediaminetetraacetate, and tritiated H_2O, resp.) as radioactive tracers in a preliminary investigation of the ground water flow in gracifluvial sand in the Nybro esker near Kalmar in Sweden. —*CA*

Certain Peculiarity of Ground Water Behavior of the Tazhi Estuary Region in the Arid Volga Plain Region. G. Y. Bogdanov. *Trudy Moskov. Geol.-Razvedoch. Inst. im S. Ordzhonikidze*, 35:45 ('59). Special wells were drilled in 1953 in the Tazhi estuary region for ground water observation. There are regular fluctuations in ground water level (spring rise, and summer, fall, and winter drops). The spring rise is 0.6-1.7 m in the estuary, 0.2–0.5 m in the plain. The relative level of the ground water in the estuary is lower than in the plain; this suggests the draining of the plain (up to 12 km). The water balance shows that the infiltration is 29 mm/year and transpiration by plants is 66.6 mm or 229.7% of infiltration. The value of side inflow is 46.6 mm (160.7% of total supply) and outflow is 4.3 mm or 14.8%. Hence, the water entering the estuary is consumed by evapn. The dynamics of the sep. components of the balance are represented in graphical form. The detailed water anal. of 14 wells gives a good characteristic of ground waters and helps in understanding the soil mechanics of the region. The mineralization of surface waters is 0.3 g/l. Therefore, together with surface waters, 2,400 tons/year of salts are carried into the estuary (area 500 sq km), and about 15,000 tons is delivered by the ground waters. Of the 17,500 tons delivered, only a small part is dissipated or consumed by plants and removed. Therefore, in the process of geol. evolution, the plain soils and the plain ground waters are losing salts, and in the estuary the accumulation transforms a fertile into an alk. saline soil.—*CA*

Geology and Ground Water Features of the Eureka Area, Humboldt County, Calif. R. E. Evenson. *USGS Wtr. Supply Papers*, 1470 ('59). There is a moderate pumpage for irrigation and domestic use. The water is generally of good qual. with moderate Ca and Mg bicarbonate hardness. The aquifers range in age from Pleistocene to recent.—*CA*

(Continued on page 86 P&R)

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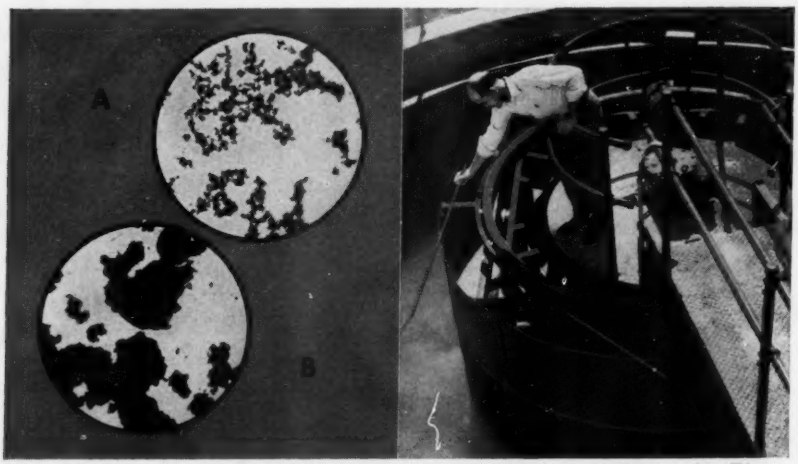

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HEALTH AND HYGIENE

Some Data on the Hygienic Importance of Nitrate in Water Supply. F. N. Ssubbotin. *Hyg. & Sanit.* (Moscow), 23:27 ('58). Data are given of the concn. of methemoglobin found in the blood of children of different ages using water with different concn. of nitrate.—*WPA*

Hygienic Considerations of Water Supply. K. Haack. *Gas- u. Wasserfach.* (Ger.), 100:1079, 1195 ('59). The author deals with the hygienic requirements of water supplies and the history of their development to modern hygienic standards, with special reference to the development of bact. knowledge. Various occurrences of epidemics of typhoid and paratyphoid and the lessons to be learned from them are described. The difficulties of hygienic control of supplies in small communities, the importance of chlorination and the risks of dependence on disinfection, and the necessity of protecting the gathering grounds from pollution are then considered. The second part of the article deals with the hygienic effects of the various methods used for the treatment of water, the problem of the addition of substances such as fluorine to a supply, and modern advances, especially in the removal of solid matter and in the examn. of water.—*WPA*

Sanitary Assessment of the Consequences Resulting From the Flooding of Tree Vegetation During Preparation of Water Reservoir Beds. I. A. Kibalchich et al. *Hyg. & Sanit.* (Moscow), 25:15 ('60). Investigations were carried out on the large Kuibishev and Kamsk reservoirs, USSR, to det. the effect on the qual. of the water of the trees, shrubs, and other vegetation which were left intact on the ground that was to form the bed of the reservoirs when they were flooded. No unfavorable effects on the qual. of the water were found. In working out the series of measurements for the clearing of tree vegetation before the formation

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of a reservoir, the authors point out the necessity of considering the ratio between the volume of the water in the reservoir and that of the org. matter to be flooded, the rate of flow of the water out of the reservoir, the existence of shallow water areas, and the climatic conditions.—*WPA*

Biologic and Therapeutic Actions of Naturally Occurring Minerals Prepared From Spring Waters. J. Kaminopetrou & M. Pertesi. *Arch. Iatrikon Epistimon* (Greek), 15:1 ('59). Curative spring water anals. are tabulated, together with a study of the bacteria-produced chlorides of local springs. Results are stated for the inorg. elements, including the gases, and for CO_2, H_2S, and CH_4.—*CA*

Biologic and Therapeutic Action of Naturally Occurring Minerals Prepared From Spring Waters. J. Kaminopetrou & M. Pertesi. *Arch. Iatrikon Epistimon* (Greek), 15:92 ('59). An exhaustive chem. analysis of local Greek mineral waters for rare and trace elements, as well as others, is given, with a discussion of their therapeutic functions in deficiency diseases and the increasing momentum in this type of research.—*CA*

The Significance and Determination of Nitrate Content of Drinking Water. H. Gartner & H. H. Staak. *Gesundh-Ingr.* (Ger.), 81:117 ('60). High nitrate concns. in water used to reconstitute dried milk can lead to methemoglobinemia. If nitrate concns. in drinking water are 40–100 mg/l, the possibility of disease formation exists; if concn. exceeds 100 mg/l, danger of methomoglobinemia exists if the water is used to reconstitute dried milk to be used in an infant's diet.—*CA*

Chronic Toxicity Studies. 1. Cadmium Administered in Drinking Water to Rats. L. E. Decker et al. *AMA Arch. Ind. Health*, 18:228 ('58). The toxicity of cadmium from inhalation of cadmium oxide or cadmium sulfide fumes in certain industries has been well established, and exptl. studies in which cats and dogs were similarly exposed have also shown cadmium to be toxic. In addition, acute cadmium poisoning has been caused by contmn. of food in contact with utensils plated with this metal. Toxicity of orally administered cadmium chloride has been reported in several animal expts., and the influence of diet on toxicity has been studied. Rats receiving 50 ppm cadmium in water exhibited reduced blood hemoglobin and stunted growth when compared with rats receiving the same amt. of cadmium in their food. The present study was undertaken to investigate the effects of long-term ingestion and retention of cadmium in tissues at low-intake levels such as might be encountered in water supplies. Five groups of rats were given water containing 0.1–10 ppm cadmium for 1 year. No difference between these groups and controls were observed in water intake, food consumption, or body weight, nor were any pathologic changes in blood or other tissues noted. Cadmium cont. of either liver or kidney increased in direct proportion to the cadmium intake. Kidneys retained 2 to 3 times the amt. of cadmium retained by the liver when calculated as micrograms of cadmium per gram of fresh tissue. Tissue values obtained at the end of a year's ingestion were roughly double in growth rate and water consumption, and blood hemoglobin was found in rats ingesting 50 ppm cadmium for 3 months. Bleaching of incisors was also observed in these animals.—*BH*

Hygienic Background for Determining the Maximum Permissible Concentration of Trichlorobenzene in Water Basins. K. F. Meleshchenko. *Hyg. & Sanit.* (Moscow), 25:13 ('60). Investigations were carried out to det. the MPC of trichlorobenzene in the water of reservoirs. The threshold level for taste and odor was found to be about 0.03 mg/l. The process of self-purification in water was inhibited by trichlorobenzene in a concn. of 5 mg/l, but not in a concn. of 2 mg/l. Toxicity tests with white rats showed that, in doses of 0.01 mg/l kg of body weight, for a period of 5.5 months, trichlorobenzene caused various functional disturbances, but no effects were observed in similar tests with doses of 0.001 mg/kg of body weight, which corresponds approx. to a concn. of 0.003 mg/l in water. It is recommended that the MPC for trichlorobenzene in the water of reservoirs should be 0.03 mg/l.—*WPA*

Carcinogens in Water and Soil. IV. Feeding Experiments With 3,4-Benzopyrene and Detergents. J. Borneff. *Arch. Hyg.*

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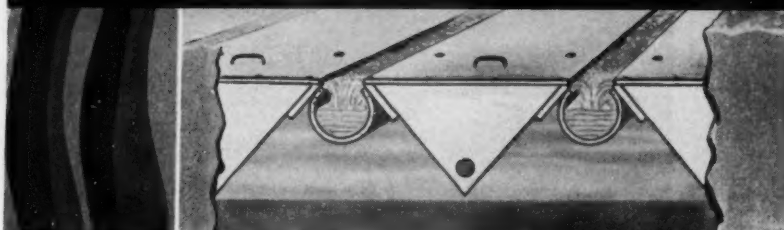

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u. Bakteriol. (Ger.), 144:249 ('60). The action exhibited by detergents on the development of carcinoma of the stomach of mice has been examd. 3,4-Benzopyrene (25 γ daily/mouse during 400 days) produced carcinoma only when benzopyrene solubilized by surface-active agents was given in drinking water. The solubilization of carcinogenic compds. by detergents contained in waste waters, or in surface waters contamd. by waste waters, is quite conceivable; exptl. proof of this is still lacking. Solid dry food with added 3,4-benzopyrene plus water and 3% detergent did not result in a higher frequency of papilloma than the same combination without detergent. Drinking water obtained from rivers subject to contamination with waste waters contg. detergents must be considered, for the present, injurious to health.—*CA*

Lead in Domestic Water Supply. Lead Piping as a Source of Toxic Quantities. C. R. Jolliff et al. *Nebraska State Med. J.*, 44:156 ('59). Pb, 0.4 ppm before and 0.03 ppm after flushing, caused the basophilic stippling in 3 subjects, without the Pb line of the gums. Coproporphyrin III, occurring in the urine, was the best indicator of Pb poisoning. Pb, 0.18 mg/l, was found in the urine.—*CA*

The Problem of Sanitary-Hygienic Assessment of the Oxygen Demand of Bog Waters. P. F. Voronin. *Chem. Zbl.* (Ger.), 129:227 ('58). The author describes comparative results using the permanganate and the potassium dichromate methods for detg. oxygen demand in water containing much fresh organic pollution, and discusses the advantage of using both methods for bog waters.—*WPA*

CHEMICAL ANALYSIS

The Determination of Total Carbonic Acid in Water With Versene. P. Berbenni. *Boll. lab. chim. provinciali* (Bologna), 11: 249 ('60). The procedure is applied to mineral waters. CO_2 is pptd. with a standard

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soln. of Ca, and the excess Ca is detd. by titration with a standard soln. of disodium ethylenediaminetetraacetate, with murexide as an indicator.—*CH*

Sampling Tidal Waters. L. WILKINSON. *New Zealand J. Sci.*, 2:196 ('59). An investigation was made of tidal influences on the compn. of the waters in 2 low-lying rivers flowing into a common estuary with a narrow outlet to the sea. Data indicated that a few low-water samples provided almost as much information regarding poln. incidence at any given point as did many samples taken at all tide stages. Chloride, pH, ammoniacal N, albuminoid N, O, and coliform count data are summarized.—*CA*

Rapid Field Determination of Sulfates, Chlorides, and Nitrates in Water, in One Sample. D. CEAUSESCU. *Acad. rep. populare romine, Baza cercetari stiint. Timisoara, Studii cercetari stiint. chim.* (Bucharest), 6: 61 ('59). Shake the sample with a cation exchanger in H form, and filter. Titrate the acids thus liberated ($H_2SO_4 + HCl + HNO_3$) with $Ba(OH_2)$, with phenolphthalein as indicator. Titrate the Ba ions of the soln. ($Cl^- + NO_3^-$) with K stearate; use phenolphthalein as an indicator of hydrolytic pptn. Titrate the Cl^- ions with $AgNO_3$ in the presence of K_2CrO_4; at the same time the Ba stearate is quant. transformed into Ag stearate, which must be taken into account when making the calcns. —*CA*

Distribution of Some Chemical Values in Lake Erie. P. R. BURKHOLDER. *US Fish Wildlife Serv., Spec. Sci. Rept., Fisheries,* No. 334, 71 ('60). Anals. are discussed of samples taken from the surface, subsurface, and bottom from 20 points in 1928 and 60 points on the open lake in 1929. Detns. were made of albuminoid NH_3, free NH_3, nitrate N, dissolved O, phenolphthalein alky., methyl orange alky., H^+ concn., Cl^-, and turbidity. Vertical, horizontal, and seasonal variations are presented. A graphical method for locating a source of pollution and detg. the rate of recovery with respect to distance downstream is given.—*CA*

Experiences With Electrochemical Oxygen Determination in Liquids Developed in Recent Years. F. TODT. *Chemiker-Ztg.* (Ger.), 83:483 ('59). For the control of O content in water effluents, the various possibilities of measuring the dissolved O are reviewed. The electrochem. measurement affords in many cases advantages and reproducibility, which, at suitable flow rate, is attained with rapid indication and high accuracy. For open and closed flow vessels, different measuring heads with electrodes of high overvoltage were chosen. This enabled one to obtain rapid attainment of the final values and also afforded wider pH range coverage. On the basis of numerous examples dealing with chem. and biol. reactions of O metabolism, the potentialities and accuracy of electrochem. O detns. were illustrated.—*CA*

Diurnal Rhythm of Oxygen in the Tordino River (Teramo, Italy). G. MORETTI; L. FORMICONE; & L. CHIARINI. *Natura* (Milan), 49:127 ('58). A graph and table of the O content of the river water from August 1955 to December 1956 are reported. O content was due to turbulence, but chiefly also to the photosynthetic activity of algae. In fact, the max. O concns. (up to 13.28 mg/l) were detd. during the hours of max. light intensity. In summer, the difference between O content in the morning, midday, and night was max.; in spring and fall, min. The photosynthetic process did not stop even in winter.—*CA*

Determination of Trichlorobenzene in Water and Measuring Its Solubility. K. F. MELESHCHENKO. *Gigiena i Sanit.* (Moscow), 25:54 ('60). The $C_6H_3Cl_3$ is extd. with Et_2O, the Et_2O dried with Na_2SO_4 and evapd., the residue is oxidized with $K_2Cr_2O_7$ and H_2SO_4, the Cl_2 formed swept by a stream of air into a CdI_2 soln., and the amt. of I liberated detd. volumetrically or colorimetrically with starch. Only 1 Cl atom is liberated/mol. The soly. of $C_6H_3Cl_3$ is 30 mg/l, which concn. is reached after 5 days. —*CA*

Determination of Chromate Ion With a Detector Tube. Y. KOBAYASHI. *J. Appl. Chem.* (London), 9:429 ('59). A tube contg. silica gel impregnated with Pb acetate is used for rapid detn. of CrO_4^{--} (>2 ppm) in H_2O. The length of the colored layer is independent of pH 2.0-8.0 and of temp. 15-60°C. The error is <10%.—*PHEA*

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Hydrochemical Criteria in the Area of Petroleum-Bearing Structures of the Stalingrad Land Along the Volga. E. S. Gavrilenko. *Trudy Inst. Nefti, Akad. Nauk S.S.S.R.* 9:253 ('58). In the area considered, hydrochem. data reflect an entirely definite regularity, which includes the fact that in chem. compn., among ground and surface waters, regionally distributed waters are distinguished, which consist of hydrochem. backgrounds and waters, the compn. of which can be considered as hydrochem. anomalies. The present report discusses the distribution, geographically, of different chem. types of waters and the geol. characteristics and tectonic structure of the region studied.—*CA*

Chemical Investigations of Hot Springs in Japan. Hot Springs of Narugo, Miyagi Prefecture. Y. Uzumasa & H. Akaiwa. *Nippon Kaguku Zasshi,* 81:567 ('60). Chem. anals. are given of 6 hot springs of Narugo. The pH ranges from 2.4 to 9.4. Variations with pH of the ratios of Cl^-, Ca, and K to Na; of Na, Ca, SO_4^{--}, and Cl^- to residue on evapn.; and of SO_4^{--} to Cl^- are examd. Higher concns. of Mn, Cu, Pb, and Zn are found in springs of low pH. It is considered that the hot springs of Narugo have originated from 2 different sources; one is high in temp. and alk. and comes from deep places, and the other is low in temp. and acid and comes from near the surface.—*CA*

Spectrographic Determination of Trace Elements in Lake Waters of Northern Maine. M. D. Kleinkopf. *Bul. Geol. Soc. Am.,* 71:1231 ('60). The methods developed for the reconnaissance prospecting of remote areas are described in detail. The 12 elements selected for spectrographic detn. are Mn, Pb, Ag, Zn, Cu, Ni, Zr, V, Mo, Cr, Sn, and Ti, and their distribution patterns are given. Samples were collected in polyethylene bottles, evapd. to dryness, ashed, mixed with C, and arced; semiquant. evaluation of the metal content was obtained by visual comparison of spectral-line intensity with that of synthetic standards. A detailed study of 3 lakes showed that, in general, variations are not great laterally or with depth for any one element, and suggests the reconnaissance value of the analysis of even a single sample as representative of the lake as a whole. The metal content is expressed as the wt. % of the recovered residue rather than as the abs. metal content/vol.; this largely eliminates the effects of changes in rates of erosion and amts. of rainfall and runoff.—*CA*

The Chronometric Approximate Quantitative Determination of Potassium in Natural Waters. D. Ceauzescu. *Acad. rep. populare Romine, Baza cercetari stiint. Timisoara, Studii cercetari stiint., Ser. stiint. chim.* (Bucharest), 4:103 ('57). This method is based on the correlation between the concn. and the time of appearance of the ppt. of Na and K hexanitrocobaltate. The ppt. appears under the specified conditions for 250 mg/l immediately; 100 mg/l after 8–10 min; 50 mg/l after 15–20 min; 25 mg/l after 45–60 min; 125 mg/l after 1.5–2 hr; and 6.5 mg/l after 3.5–4 hr.—*CA*

Trace Elements in Hungarian Waters. Z. Nagy & E. Polyik. *Hidrol. Kozlony* (Budapest), 37:166 ('57). The dry residue from 50–100 ml H_2O is investigated spectrographically. The substance is placed into the cavity formed in spectrally pure C and evapd. in an a.-c. arc. Of the trace elements, Ti, Mn, Cu, V, Al, Pb, Sr, and Ba are the most frequent; As, Be, Cd, Co, Mo, and Ni are rarer elements. Much alkali interferes with the detn. —*CA*

Practical Application of the Electrochemical Determination of Oxygen in Water. II. Short-Time Test; the Oxytester. H. Ambuhl. *Schweiz. Z. Hydrol.* (Ger.), 20:341 ('58). The electrochem. detn. of O contents in lakes and activated sludge basins according to the method of Todt is investigated. The nonrecording short time test is used. Exterior influences (cond., temp., current, cathode surface) are discussed. An O sounder with good properties as regards mech. strength and sensibility of the electrodes is described. As a further development, combined sounders, called "Oxytester," for measuring temp. and O, were designed. The disturbing influence of temp. on the testing of O is compensated electrically. Tests with the oxytester in lake investigations reveal continuous profiles of O, temp., and cond. In this way fine proportions of stratification can also be ascertained precisely. Possibilities of measuring by sounders are illustrated by the test profiles from studies made of lakes in the Swiss Midland.—*CA*

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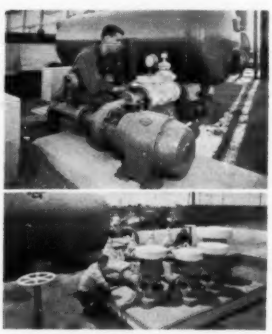

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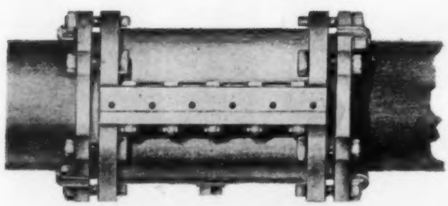

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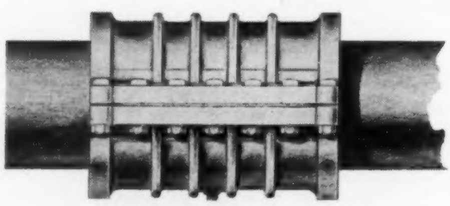

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EAST ORANGE, NEW JERSEY

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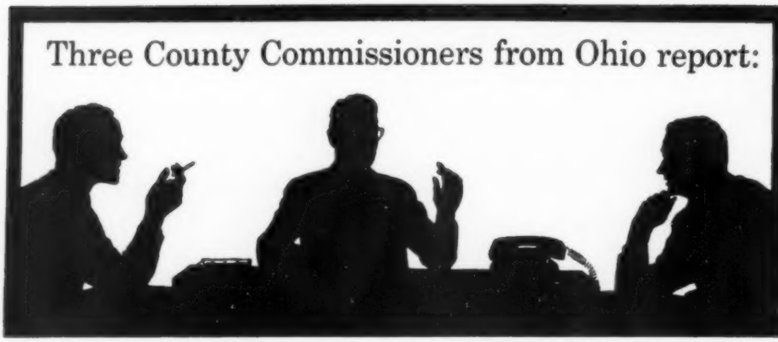

"For economy and performance, Transite Water Pipe is still our main choice."

"Belmont was one of the many counties that experienced a building and population boom. Fortunately, our officials had the foresight to recognize its ultimate effect on our water system and service. As early as 1953, plans were made to meet future demands. Surveys were made . . . operating men and engineers were consulted . . . pipe materials investigated.

"In 1956, we extended our water system 13 miles. The installation and operating economies are now a matter of record. The successful performance of the extension is attributed to careful planning, helpful advice and, in part, to the selection of Transite Pipe.

Belmont County, Ohio, Commrs. William H. Dorsey, Austin C. Furbee and Louis T. Salvador.

"When we began designing another expansion of the system for 1960, our previous experience made Transite the main choice. The Belmont Water System now has 53 miles of Transite installed in rocky terrain and corrosive soils. The excellent performance of the first 13-mile section leads us to believe that Transite will provide economical maintenance and operation for many years."

For the full Transite® story, write Johns-Manville, Box 14, JA-5, New York 16, N. Y. In Canada: Port Credit, Ontario. Cable address: Johnmanvil.

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TRANSITE PIPE
THE WHITE PIPE THAT PROTECTS PRICELESS WATER

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